I APPENDIX I: TAPERED ELEMENT OSCILLATING MICROBALANCE

STATE OF IDAHO

DEPARTMENT OF ENVIRONMENTAL QUALITY

AIR MONITORING QUALITY ASSURANCE

STANDARD OPERATING PROCEDURES

FOR

AIR QUALITY MONITORING

Rupprecht and Patashnick 1400AB Continuous Ambient Particulate (PM_{10} and $PM_{2.5}$) Monitor

NOVEMBER 2004

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CONTINUOUS AMBIENT PARTICULATE MONITOR

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RUPPRECHT and PATASHNICK 1400AB

CONTINUOUS AMBIENT PARTICULATE MONITOR

TABLE OF ACRONYMS, UNITS, AND CHEMICAL NOMENCLATURE

AQS	Air Quality System
AQA	Air Quality Advisory
ACCU	Automatic Cartridge Collection Unit
Cm	centimeter
CFR	Code of Federal Regulations
DAS	Data Acquisition System
DOS	Data Operating System
in-Hg	inches of mercury
Lpm	liters per minute
MFC	Mass Flow Controller
Ml	Milliliter
mm Hg	millimeters of mercury
NIST	National Institute of Standards and Technology
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
PM_{10} or $PM_{2.5}$	Particulate matter with aerodynamic diameter of 10 or 2.5 μm
PRC	Program Register Code
RFD	Reference Flow Device
TEOM	Tapered Element Oscillating Microbalance
Mm	Micrometer
VAC	Volt, Alternating Current

Rupprecht and Patashnick 1400AB Continuous Ambient Particulate (PM_{10}) Monitor

STANDARDS: State: Federal Standards adopted by Idaho
Federal: PM_{10} Primary and Secondary
150 µg/m^3, 24 hour average (99th% averaged over 3 years).
50 µg/m^3, annual arithmetic mean.

$PM_{2.5}$ Primary and Secondary
65 µg/m^3, 24 hour average (98% averaged over 3 years).
15 µg/m^3, annual arithmetic mean averaged over 3 years.

METHOD: (TEOM) Model 1400AB. Equivalent method designation EQPM-1090-079
ANALYTE: Suspended particulate 2.5 or 10 microns in diameter
PROCEDURES: Oscillating microbalance
RANGE: Less than 5 µg/m^3 to several grams/m^3
MANUFACTURER: Rupprecht & Patashnick Co. Inc. Albany, NY

I.1 GENERAL INFORMATION

The Tapered Element Oscillating Microbalance (TEOM) is a continuous particulate monitor that received EPA Equivalent Method designation in October 1990 for measuring the airborne concentration of particulate matter 10 micrometer (µm) in aerodynamic diameter (PM_{10}). By simply exchanging the size selective inlet, the TEOM can also be used for measuring the airborne concentration of particulate matter 2.5 µm in aerodynamic diameter ($PM_{2.5}$), but thus far the TEOM has not yet been designated by the EPA as an equivalent method for $PM_{2.5}$ monitoring.

Department of Environmental Quality (DEQ) TEOMs serve two primary functions in Idaho's particulate monitoring network:

1) Monitoring for compliance determination of the 24-hour and annual National Ambient Air Quality Standards (NAAQS) for PM_{10}
2) Monitoring support for the Air Quality Advisory program (AQA)

Because the TEOM has not yet been designated as an equivalent method for $PM_{2.5}$ monitoring, DEQ cannot use the TEOM as a $PM_{2.5}$ compliance monitor, although it will be used for AQA monitoring support. Should the TEOM be designated as an equivalent method for $PM_{2.5}$ monitoring in the future, the TEOM would likely play a significant role in $PM_{2.5}$ compliance monitoring in the DEQ air-monitoring network.

I.1.1 SCOPE

This appendix of the Idaho Ambient Air Quality Monitoring Quality Assurance Project Plant (hereafter referred to as QAPP) covers the operation and maintenance of the Rupprecht and Patashnick (R&P) 1400AB TEOM. The information contained in this section is supplemental to the R&P Operational Manual (hereafter referred to as R&P Manual) which should be the first source of information for the set-up, operation, and maintenance of the TEOM. This quality assurance (QA) appendix addresses operation and maintenance parameters that may or may not differ from the R&P Manual but highlights common functions performed by the TEOM operator, or functions that tailor use of the TEOM to meet the specific needs of DEQ's monitoring network. Where needed, this appendix will reference the appropriate section of the R&P Manual for information relative to the specific section of this appendix. The successful operation of the TEOM is dependent upon properly trained operators. Therefore, it is necessary that any person responsible for the daily maintenance and operation of the TEOM be fully trained by R&P or a qualified operator within the DEQ organization.

I.1.2 THEORY OF OPERATION

The first step of TEOM operation is particle separation, which occurs by drawing a controlled volume of air (16.7 liters per minute [lpm]) through a size selective inlet. Particle separation occurs by accelerating the air stream through a series of turns where the larger particles are removed by inertial impaction. At the exit of the inlet, the flow is split isokinetically into a 3 lpm and a 13.7 lpm air stream called the main flow and bypass flow, respectively. The bypass flow is available for the operation of the TEOM Automatic Cartridge Collection Unit (ACCU) system. This system allows for the placement of Teflon or Quartz fiber filters in line for speciation analysis. At this time no ACCU system is being employed by DEQ so the bypass flow is exhausted to the atmosphere. The main flow, which contains the analyte fraction of particulate, is sent to the instrument's mass transducer. See Figure I.2.1 for a diagram of the flow system.

The mass transducer in the sensor unit has a tapered ceramic tube (element) that is fixed at the downstream end and has a filter attached on the free upstream end. As air is drawn through it, the element vibrates much like the tine of a tuning fork. The frequency of oscillation is dependent upon the physical characteristics of the tapered tube and the mass on its free end (i.e. the filter) - as the filter continuously loads with particulate matter, the oscillation frequency of the element changes proportionally. A sensor unit monitors the vibration and sends information to the control unit/microprocessor that converts it into a particulate concentration by dividing the mass rate of accumulation by the flow rate. The internal data-logger is capable of storing values in instantaneous (real-time), 30-minute, hourly, eight-hour, and 24-hour averages.

To reduce the bias caused from atmospheric moisture, the sample stream entering the TEOM sensor unit is heated to minimize water collection on the sample filter. The operator of the TEOM must be familiar with the series of temperature controls of the sample stream. These are called the Air, Cap, Case, and Enclosure temperatures. As air is drawn into the TEOM, the sample stream (main flow) is heated at the base of the air inlet (air temperature). The temperature of the upper part of the mass transducer (cap temperature), the rest of the mass transducer (case temperature), and the temperature inside the sensor unit (enclosure temperature) are all controlled at specific temperature set points. These temperatures will be addressed in Section I.3.1.1.7, System Registers and the Virtual Keypad.

I.2 SITING AND SETUP

I.2.1 SITING REQUIREMENTS

A TEOM site location will allow the complete installation of all TEOM components in an appropriate indoor/outdoor environment and meet siting criteria and guidelines described in 40 CFR Part 58 Appendix E, and the Quality Assurance Handbook for Air Quality Measurement Systems Volume II, Section 2.11.3.

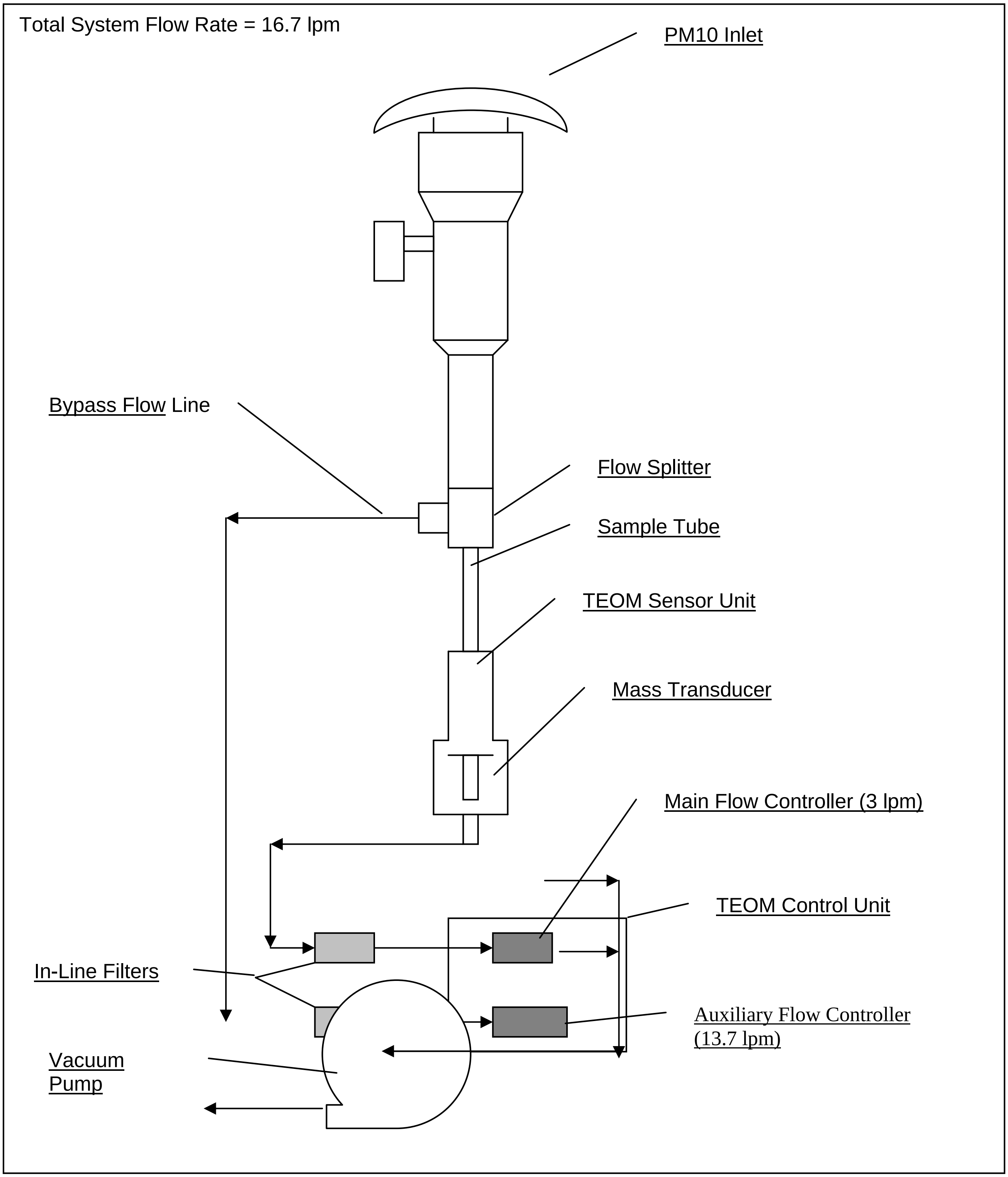


Figure I-1.TEOM Schematic Diagram

A TEOM monitoring site must accommodate the installation of the TEOM components described in Sections 2 and 10 of the R&P Manual. For installation in the optional complete outdoor enclosure, the primary factor of concern determining the placement of the sensor unit is the need for a sturdy, vibration free mounting that will be as independent as possible from other activities in the area.

Because the TEOM operates on the principle of an oscillating element, it is sensitive to vibrations. Consideration for sources of vibration should be addressed when identifying TEOM sites. For example, sites next to roads with heavy truck traffic or rooftops sites near large HVAC, or ventilation fans should be avoided.

I.2.2 INSTALLATION

Indoor installation of the sensor unit requires the following:

1) a solid table, bench, counter-top, or vibration free instrument rack
2) a straight line from the inlet of the sensor unit through a 1.5-inch diameter hole in the roof of the monitoring site
3) tripod mounting for the inlet
4) temperature and humidity controlled environment
5) accessibility to a 110 Volt, Alternating Current (VAC) power source

Outdoor installation of the sensor unit requires the following:

1) a support structure free of vibration
2) a weatherproof and temperature controlled environment
3) accessibility to a 110 VAC power source

If the outdoor installation is located on a roof, the installation must not compromise the integrity of the roof's weatherproof surface.

Caution: Any time the sensor unit or complete outdoor enclosure is moved, the sensor unit's mass transducer must be locked to avoid damaging the tapered element as described in the R&P manual.

I.2.3 SET-UP OF INTERNAL DATA STORAGE

The TEOM will store up to eight Program Register Codes (PRCs) in the internal data logger. The PRC is an identifier code assigned by R&P to help define the operation of the instrument and to identify what variables are stored in the data logger. Each parameter is stored with the date and time. The storage interval and stored parameter configuration can be edited using the keypad or the RPComm software. Stored data can be viewed by downloading through the RS-232 port with the RPComm software either onsite or via modem.

All DEQ TEOMs are set up to store the same seven data fields over a time interval of one hour. It is important for the current data processing techniques that PRC 58 and PRC 13 are stored as the third and fourth data fields in the data logger. Though it is recommended the additional data field in the DEQ TEOMs be left null, it may be used to store any additional PRC that the regional office requires to maintain proper TEOM function or to ensure valid data collection. However, since storing more than seven PRCs will create additional processing steps prior to submittal to EPA; it is recommended the state office be contacted if this additional data field will be utilized. Storage parameter consistency should be maintained, to facilitate data retrieval through DEQ's data acquisition system (DAS). New TEOMs put into service should follow the same data storage formats listed in I.2.1. The DEQ TEOM has an internal data storage capacity of approximately 10 weeks when storing seven data fields per hour. Refer to the R&P Manual for instructions on setting up the internal data logger.

I.2.4 ANALOG OUTPUT

DEQ currently has no requirements for the use of the analog outputs; however, there may be circumstances when a network operator would choose to use a strip chart recorder or an external data logger. With the limited abilities of the Idaho DAS, some monitors in critical areas may need to be equipped with additional data recording devices. Having the expanded ability to track instrument operating parameters would help to ensure that collected data meets quality assurance guidelines. Section 9 of the R&P TEOM manual addresses analog input and output specifications.

Table I-1. Data Storage Format

Storage Parameter	Stored Code	Stored Code Description
Storage Interval	3600	3600 seconds or one-hour
Storage Variable 1	041	Status
Storage Variable 2	060	24-Hour Average Mass Concentration
Storage Variable 3	058	1-Hour Average Mass Concentration
Storage Variable 4	013	Noise
Storage Variable 5	035	Filter Loading %
Storage Variable 6	012	Frequency
Storage Variable 7	009	Total Mass
Storage Variable 8	Null	N/A

I.2.5 SECURITY

In certain circumstances, users outside DEQ may be viewing data stored in the TEOM's internal data logger. In these circumstances, the lock mode capabilities of the 1400AB monitor MUST BE engaged. In a lock mode, viewing of the operation of the monitor is not restricted, only the ability to change the operating parameters or operating mode is hindered. Implementing this safeguard will remove the possibility of an inexperienced individual inadvertently suspending data acquisition. Section 4.2.1 of the R&P TEOM manual briefly describes the three levels of security available for the operator. For more detailed information, please refer to Section 11 of the TEOM manual on password protection.

I.3 TEOM OPERATION

I.3.1 COMMUNICATION

Communication with the TEOM is accomplished one of two ways. The first method is through the use of the R&P communication software called RPComm. The RPComm software is used either remotely (via modem) or on-site through the RS-232 port. The second method of communication employ's the keypad on the front of the control unit, which allows the user to directly retrieve data and enter commands. More detailed information on the use of the keypad for direct communication with the monitoring unit can be found in Section 4.3 of the 1400a (AB) TEOM Operating Manual. Additional information on connecting the monitor to a personal computer via the RS-232 ports may be obtained in Appendix D, Section D.1.2 and Section 10 of the TEOM Operating Manual.

I.3.1.1 COMMUNICATING USING RPCOMM SOFTWARE

RPComm is a software communication package for Windows 9x/NT/2000/ME used to view current instrument outputs, modify instrument-operating parameters, and download stored data. In addition, this software enables a user to schedule automatic data downloads, graph both the stored and real time data, and remotely operate or modify the unit using a virtual keypad. DEQ state and regional office personnel use this software to poll the $PM_{2.5}$ and PM_{10} TEOMs in order to update current air quality forecasts and archived data files on the shared network. The RPComm software can communicate with the control unit remotely via a modem, or directly (on-site) using the RS-232 port. The software utilizes PRCs to change or retrieve TEOM data directly from the control unit. The PRC's, and their associated parameters, are assigned by the manufacturer and listed in Appendix B of the R&P Manual. Some common PRCs are provided in Table I-2.

Table I-2. Common Program Register Codes (PRC)

PRC	PARAMETER	EXPECTED RESULT (LIMITS)
009	Total Mass (μg)	
012	Frequency	150-440 Hz
013	Noise	≤0.10 μg
014	Operating Mode	4
025	Case Temp. (current)	±0.1°C of set-point
021	Case Temp. (set)	±0.1°C of set-point
022	Air Temperature Set Point	±0.5°C of set-point
026	Air Temp. (current)	±0.5°C of set-point
027	Cap Temp. (current)	±0.1°C of set-point
028	Enclosure Temp. (current)	±0.5°C of set-point
029	Average Temperature	99°C
031	Average Pressure	9 atmospheres
035	Filter Loading (%)	>15% and < 90%
039	Main Flow (current)	3 l/min (±0.1 l/min)
040	Auxiliary Flow (current)	13.7 l/min (±0.1 l/min)
041	Status Condition	0 (signifies OK), 2 (temperature out of bounds), 4 (flow out of bounds), 8 (filter loading greater than 90%)
058	1-hour Average Mass Concentration (μg/m^3)	
060	24-hour Average Mass Concentration (μg/m^3)	

Serial outputs and two-way communications using the RPComm software are described in Appendix C of the R&P 1400a (AB) Operating Manual. It should be noted that the manufacturer periodically updates all instrument software and operating manuals. The updated versions of these files can be downloaded from the R&P home page on the World Wide Web at www.rpco.com. After accessing the home page, select the 'Customer Area' link at the bottom of the screen. A password is required for access to this area. Please contact the State Office or R&P directly for help with passwords. After successfully accessing the customer area, click on the 'Ambient' icon and select the product of interest from the 'Customer Area Ambient Products' page. For example, select '1400a' for the TEOM. The next page provides links to software downloads, technical advisories, and operating manuals. Select the appropriate operating software for the type of monitor being used. The 'rpcomm.exe' file can also be downloaded from this Web site. Choose the 'DAS Software' button in the 'Customer Area – Ambient Products' page and download the version of RPComm that best fits the operating system on your personal computer.

Accessing RPComm

The newest version of the RPComm software has been equipped with a feature known as 'Autorun'. Although this option was designed to automatically start the PRComm application upon PC startup, it may not always be operational due to network changes or computer updates. If this option has been disabled, the RPComm software may be accessed via a desktop shortcut or manually through the start menu. Once the RPComm program has been started, the RPComm main screen (Figure I-2) will appear. From the main screen, a user can establish a new connection or access an already existing one using the file menu or new connection icon (Figure I-2 and Figure I-3).

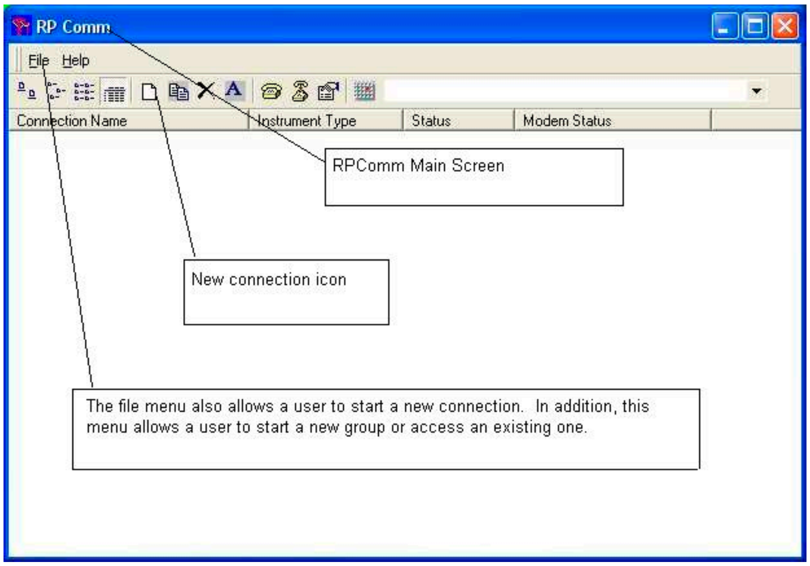


Figure I-2.RPComm Main Screen

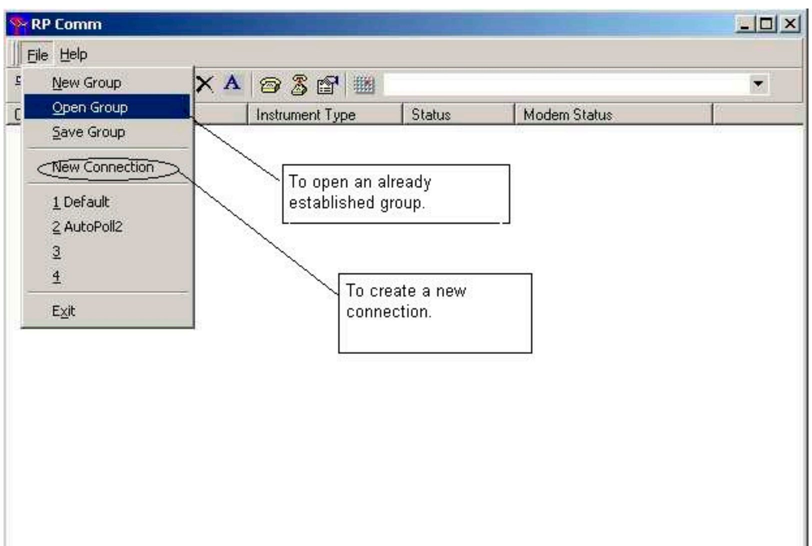


Figure I-3.RPComm File Menu

I.3.1.1.2 Creating a New Connection with RPComm

As mentioned in the previous section, a new connection may be initiated in one of two ways. The new connection option may be chosen from the file menu or the 'new connection' icon may be chosen from the tool bar of the RPComm main screen (Figure I-4). Choosing the new connection option will open the 'Connection Type' box. Select the '1400' button for either a PM_{10} or $PM_{2.5}$ TEOM and the 'Settings' option (Figure I-5) to display the 'AK Protocol Setup' screen (Figure I-6).

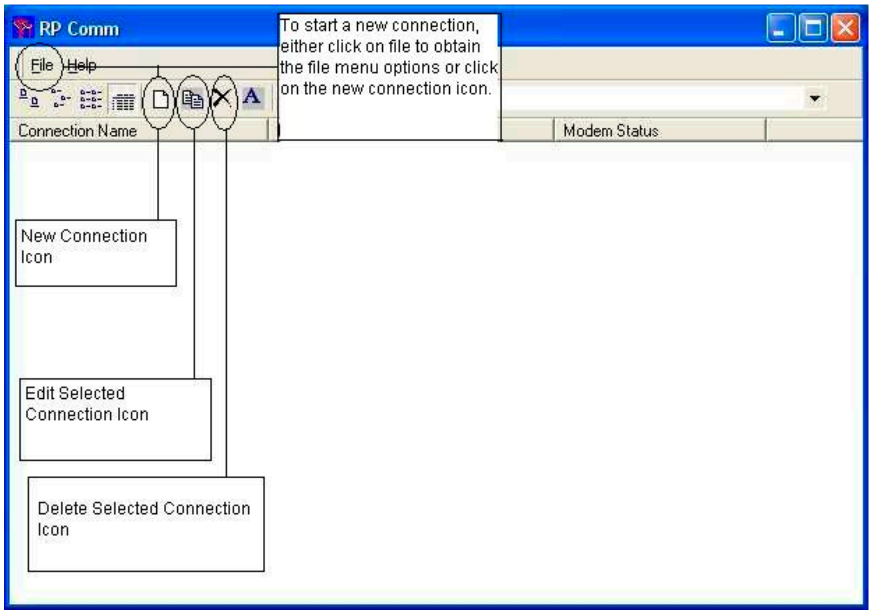


Figure I-4. RPComm Main Screen

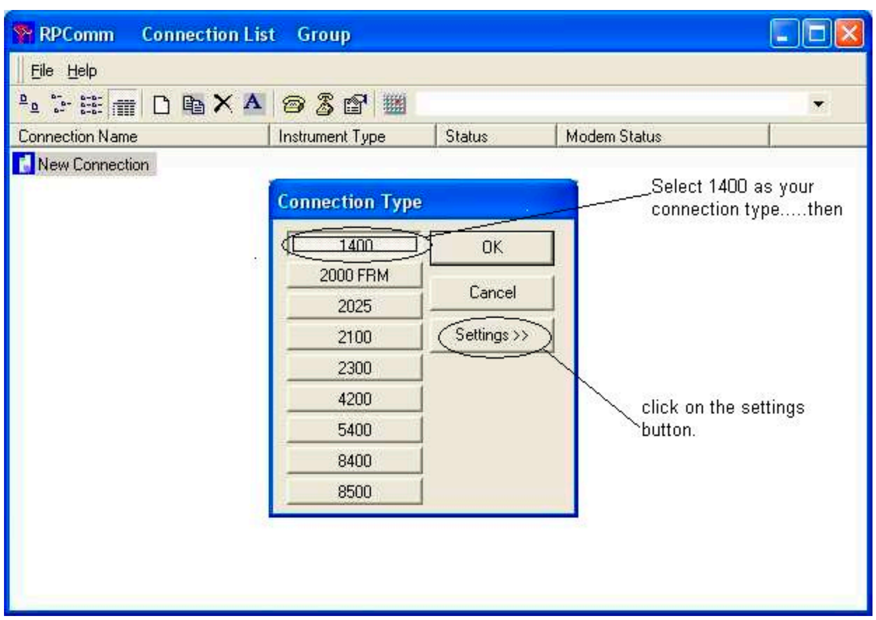


Figure I-5.Connection Type Box

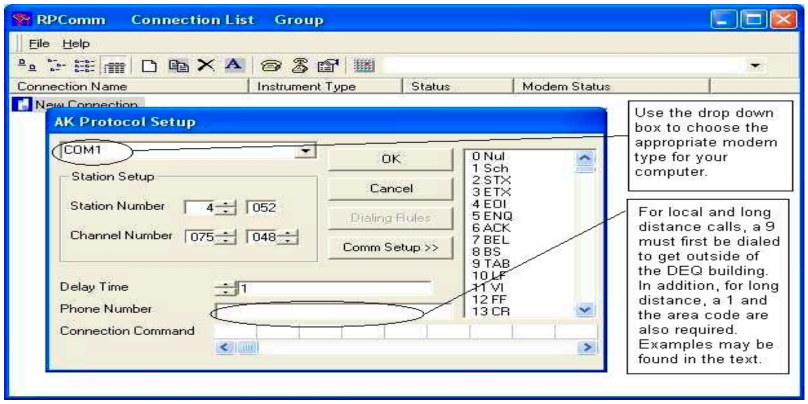


Figure I-6.AK Protocol Setup Screen

Once the 'AK Protocol Setup' screen has been displayed, the drop down arrow for the COM1 entry can be used to choose the most appropriate modem connection for your PC. For a direct connection, this box should be left as COMx where 'x' is the serial port on the computer that the sampler is directly connected to. For more information on a direct connection, please refer to Section 10.2.2 of the TEOM Manual. R&P recommends that the 'Station Setup' parameters be left at the default values. It is also recommended that the delay time be set to zero. It is at the field operator’s discretion to choose a higher value, if one is needed.

A number of dialing conventions may need to be employed by the user when establishing the communications link for a monitor. This is due, in part, to the different types of communications equipment that may be used out in the field and to the wide range of areas that may need to be covered by each regional office. While most of these conventions are similar to those used when making regular phone calls from within a DEQ building, there are a few that require additional codes due to switching boxes, voice modems and region-specific long distance calling conventions, etc. For local and long distance calls, an additional "9" is needed at the beginning of the dialing string to gain phone-line access outside of the building. A "1" and the area code must also be included when dialing a long distance number. In some cases, a regional office may have an additional code to be used with long distance numbers. This code is specific to the region and is attached at the end of the dialing string. For those sites using a switching box or voice modem additional numbers will be needed to ensure that the correct monitor is being accessed and that the voice modem is set in a data collection mode. The following figures provide examples of the various dialing strings that may be used by DEQ personnel when setting up their respective calling lists in RPComm. Take special note of Figure I-9 and Figure I-10 as these provide an example of a monitoring site where a switching box is employed.

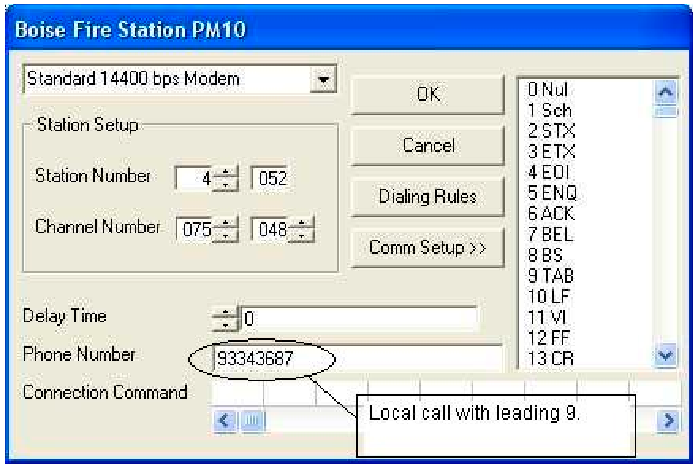


Figure I-7.Example of a Local Dialing String

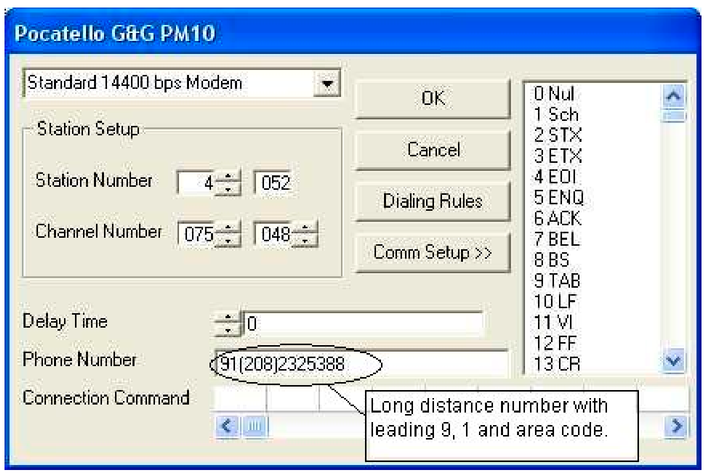


Figure I-8.Example of a Long Distance Dialing String

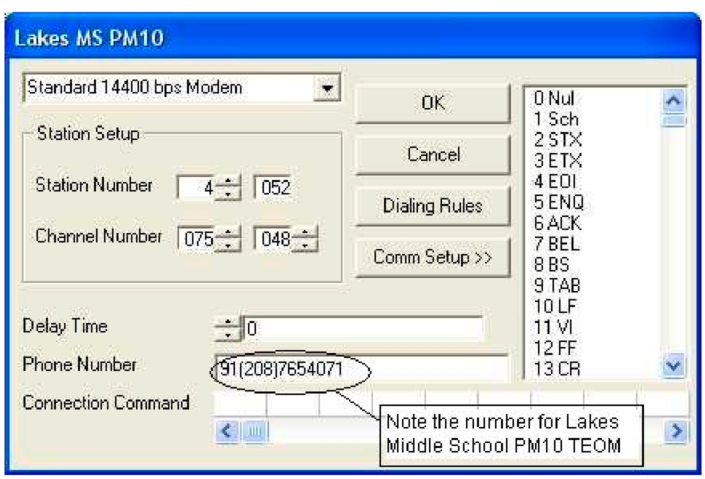


Figure I-9.Example of a Site with a Switching Box

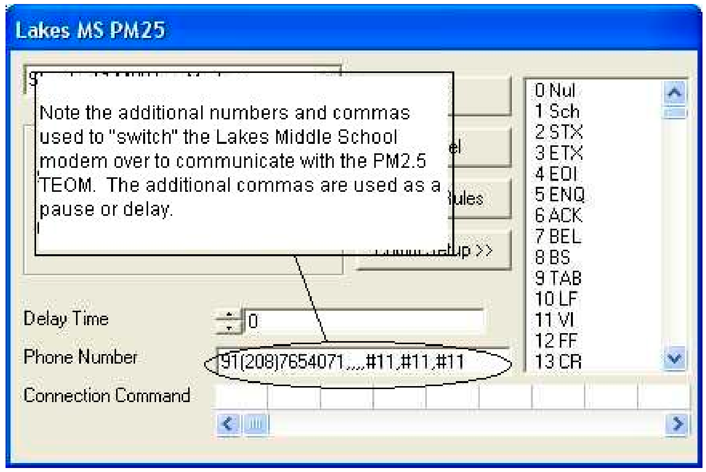


Figure I-10.Using the Switching Box to Access the PM2.5 TEOM

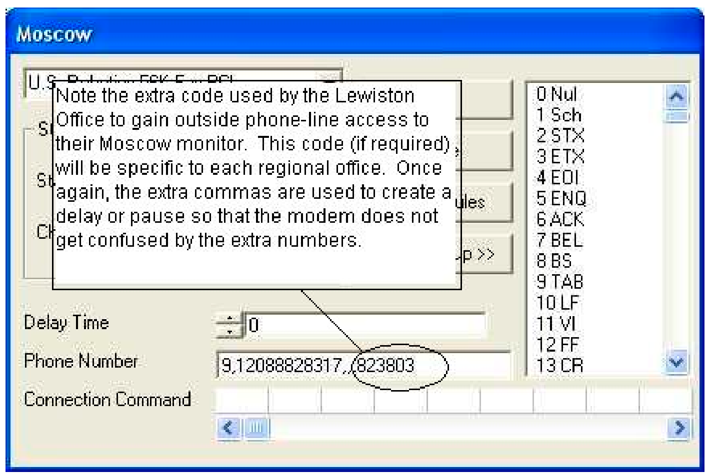


Figure I-11.Use of an Additional Code for Outside Phone-line Access

To check or change the connection settings including port speed, parity, etc., select the 'Comm Setup' button on the AK Protocol Setup screen (Figure I-12). This will bring up the 'Properties' screen (Figure I-13). Check to make sure that the country/region, area code, phone number and modem type are correct. If the country and area code need to be revised, go back to the 'AK Protocol' screen and choose the 'dialing rules' button. This will bring up the 'Phone and Modem Options' screen. Use the edit option to revise the settings. Choosing the 'new' button will allow the user to change the dial setting from tone to pulse in addition to disabling call waiting. If the port speed (baud rate) or hardware settings need to be changed, use the 'configure' button on the Properties screen (obtained through the 'Comm Setup' button of the AK Protocol Setup screen and shown in Figure I-13). The parity settings can be accessed via the 'Advanced tab' (Figure I-15).

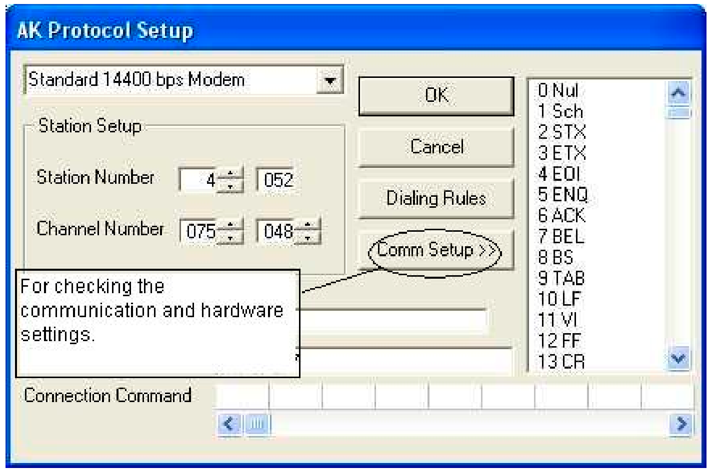


Figure I-12.Comm Setup Button

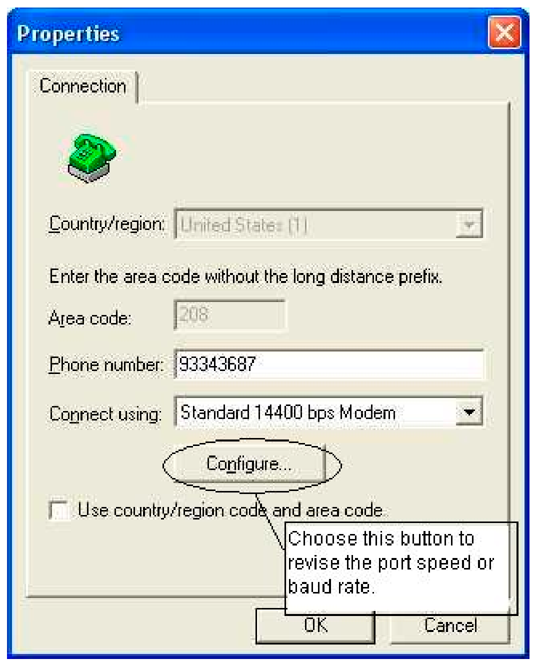


Figure I-13.Configure Button on the Properties Screen

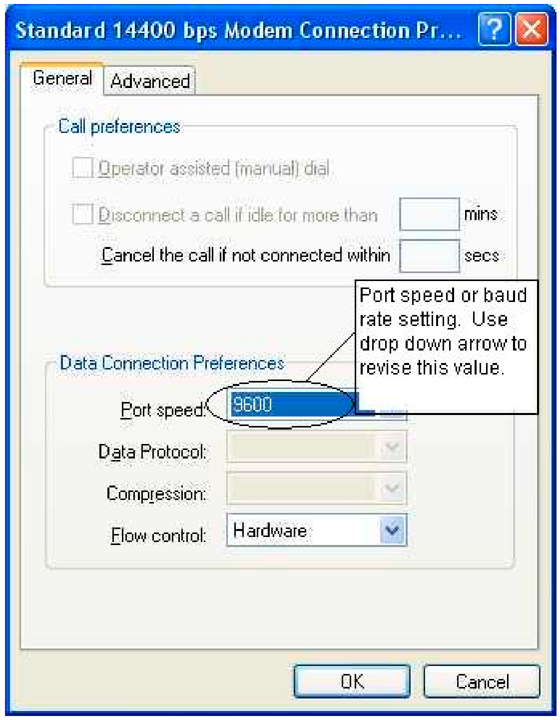


Figure I-14.Port Speed or Baud Rate Setting

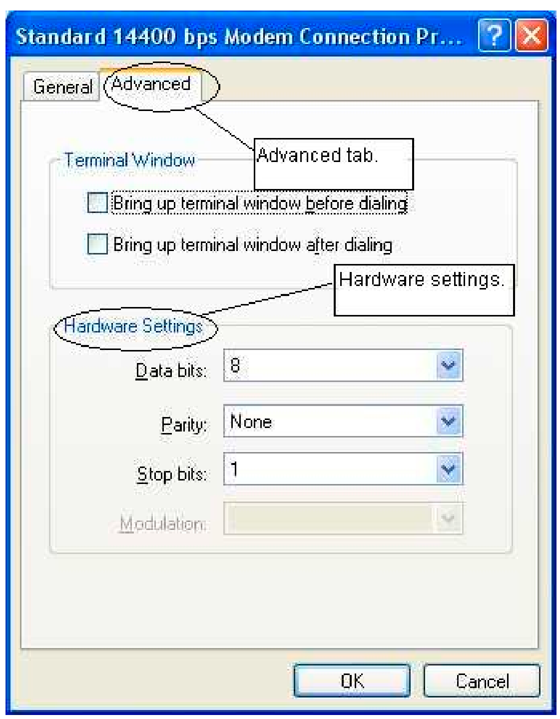


Figure I-15.Advanced Tab and Hardware Settings

By selecting 'OK' after each setting revision, the user will be taken back to the previous screen or option box. Once all of the settings have been modified to the user's specifications, click 'OK' in the AK Protocol Setup screen to go back to the 'Connection Type' screen. Selecting 'OK' in this screen, signals the end of the connection setup process. The 'New Connection' will now be displayed in the Connection List screen. To edit the new connection name, click on 'New Connection' to highlight the words and then click on them again (Figure I-16). Once the flashing cursor has appeared, use the PC keyboard to modify the name and press 'enter' to save the changes. These aforementioned steps should be followed to define each new connection.

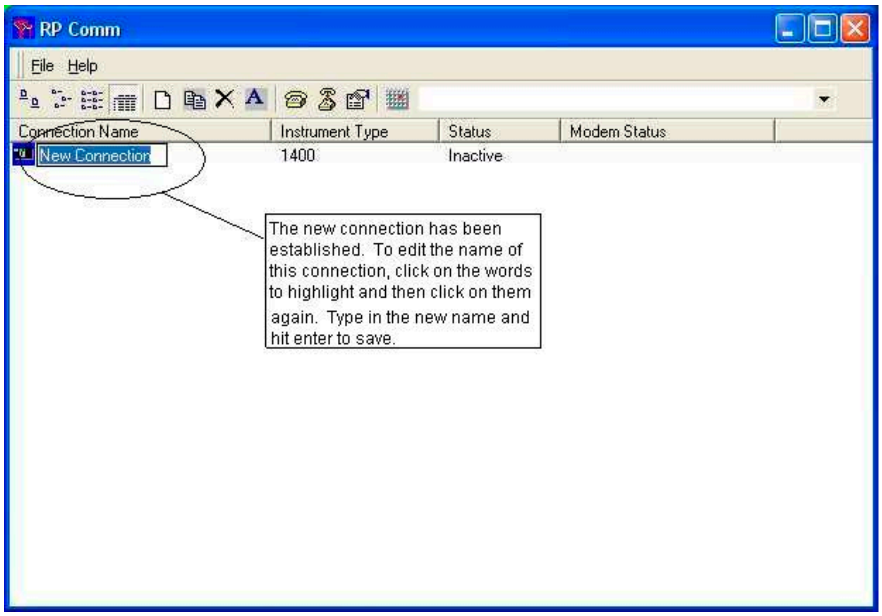


Figure I-16.Renaming a New Connection

Creating a Connection Group within RPComm

To make accessing the individual connections easier, a connection group may be established. Connection groups can consist of similar monitor types (e.g., $PM_{2.5}$ TEOMs or PM_{10} TEOMs, etc) or may consist of monitors with the same downloading schedules (e.g., monitors checked once a week, versus every other day or daily). To create a connection group, make sure that all of the new connections for that group are displayed on the Connection List screen (Figure I-17). Click on 'File' in the upper left-hand portion of the box. Choose the 'Save Group' option, name your group, and click 'OK' to save (Figure I-18 and Figure I-19). The next time that RPComm is started, the user can click on 'File' and 'Open Group' to access the newly created connection group. Highlight the group to be opened and click 'OK'.

There are a number of procedures that the operator may want to perform after making connection to a monitor via the RPComm software. The following sections will discuss the more common routines that can be carried out using the RPComm software. For more detailed information on these or less common procedures, refer to the TEOM operating manual.

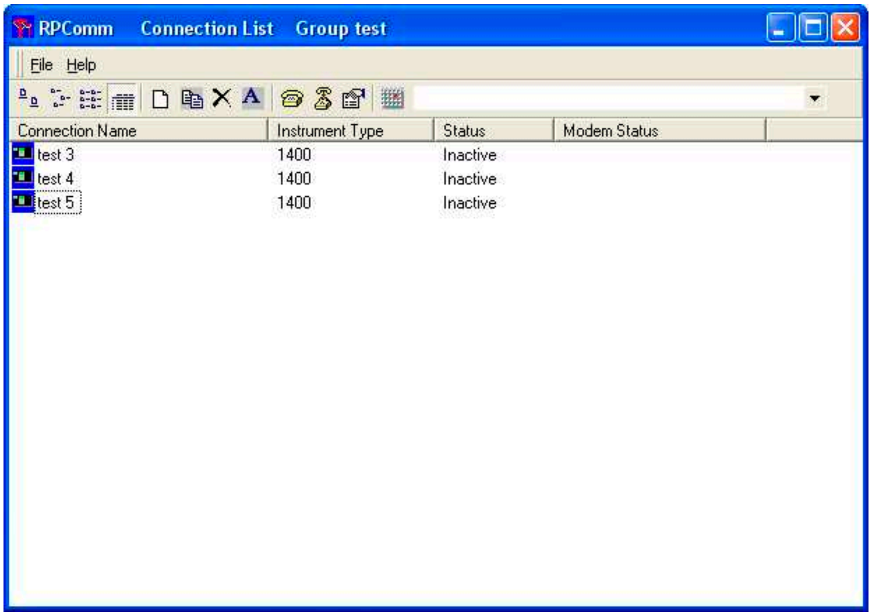


Figure I-17.Connection List Screen Showing the Newly Established Connections

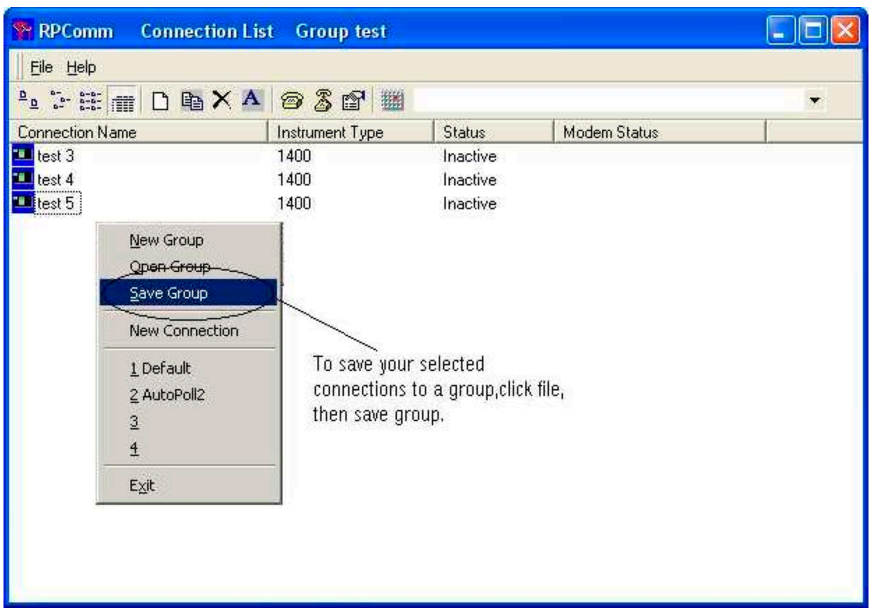


Figure I-18.File Menu Showing the "Save Group" Option

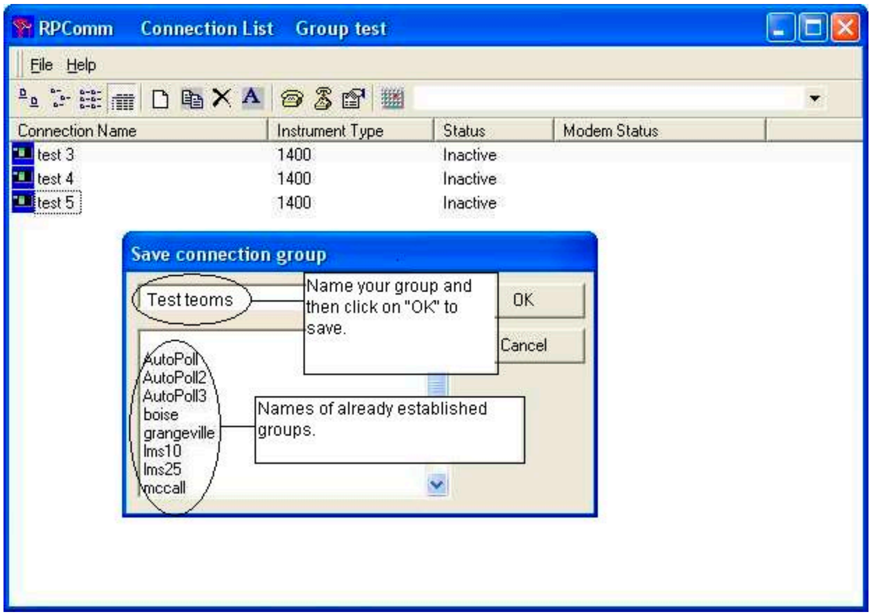


Figure I-19.Saving a Connection Group

Communicating with a Monitor and Downloading Data Using RPComm

To access a monitor via the RPComm software, use the file menu to open the appropriate group. Highlight the desired monitor connection in the Connection List screen and click on the 'Connect to Selected Instrument' icon in the RPComm toolbar (Figure I-20). This icon (also seen in Figure I-21) looks like a telephone. As seen in Figure I-21, the user can disconnect from the selected monitor, view the connection properties of that monitor, or schedule automatic downloads for the monitor using the various toolbar icons.

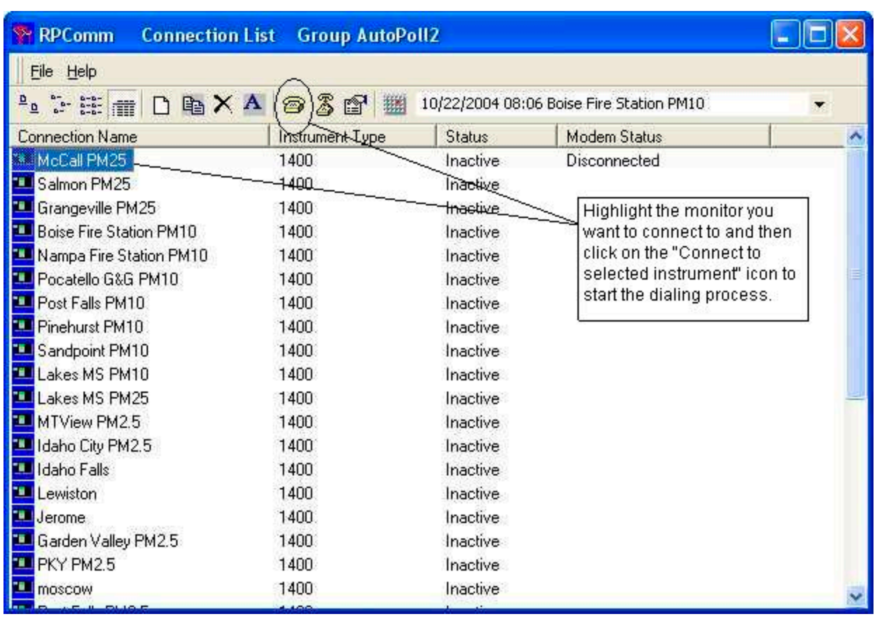


Figure I-20.Starting the Download Process

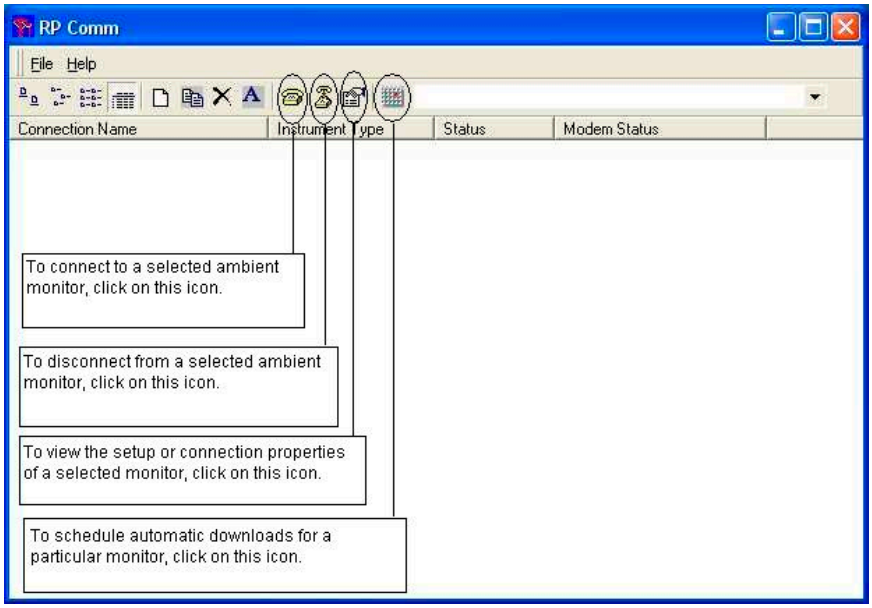


Figure I-21.Connect to Selected Instrument and Other Icons

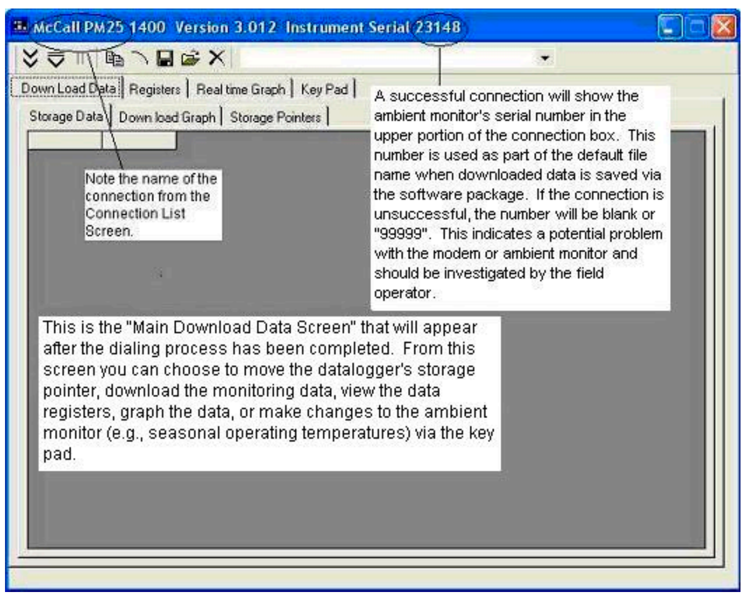


Figure I-22.Main Download Data Screen

After clicking on the 'Connect to Selected Instrument' icon, a small box will appear on the screen indicating that the dialing process has begun. Once a connection has been made, the Main Download Data screen will appear (Figure I-22). Take note of the serial number in the upper-right-hand corner of the screen. This number is unique to the monitor being queried. If the serial number area is blank or “99999”, then a successful connection has not been made. This may indicate a problem with the modem or ambient monitor and should be investigated by the field operator.

From the Main Download Data screen, select the 'Storage Pointers' tab. This shows the last record downloaded from the datalogger storage buffer in addition to the various buttons for moving the storage pointer location (Figure I-23). The drop-down menu of the Change Record Step Box can be used to change the record step interval to a value other than one. This allows the user to move the storage pointer by more than one record at a time. Moving the storage pointer allows the user to select the beginning of the data file to be downloaded. Using the icons at the top of the screen and the 'Change Record Step Box', the user can move the storage pointer either forward or backward to the desired location. Once this is done, click on the 'Storage Data' tab to get the Download Data screen (Figure I-25). The icons on this screen can be used to download the data, send it to the graphing routine, save it to a disk or to the Windows clipboard for use in another program.

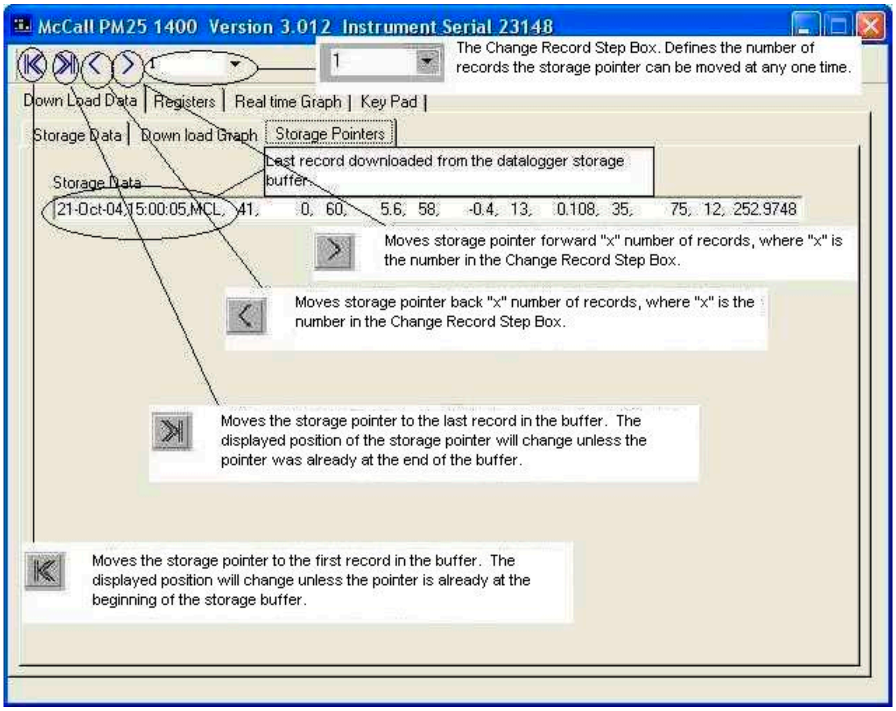


Figure I-23.Storage Pointers Tab for Moving the Storage Pointer

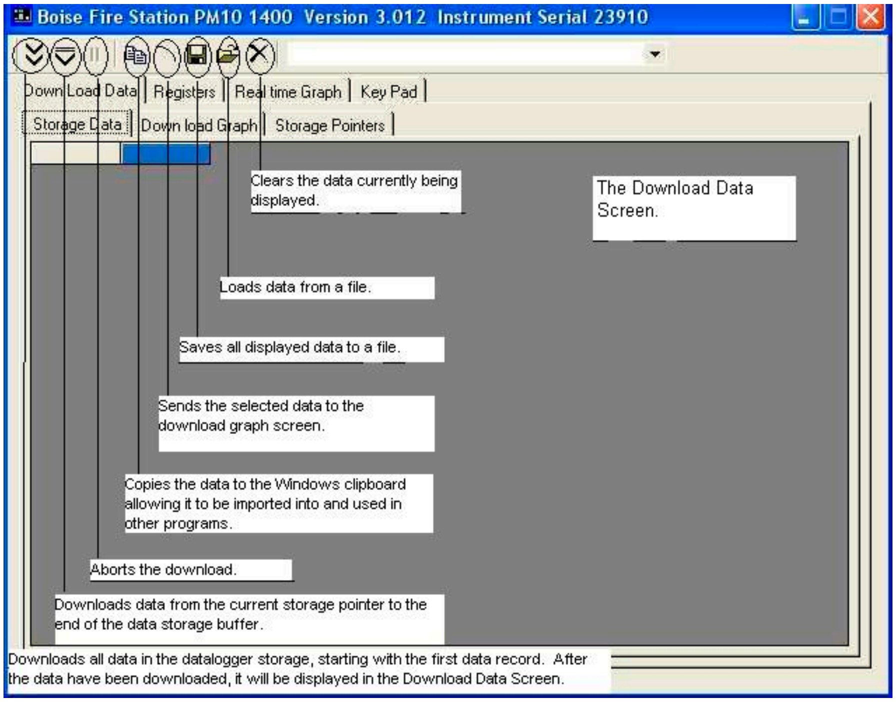


Figure I-24. Download Data Screen (via the Storage Data Tab)

To initiate the data downloading process, select the appropriate control button from those shown in Figure I-24. It should be noted that the button located furthest to the left on the tool bar downloads all of the data currently stored in the datalogger storage, while the button next to it will only download the data going back as far as the last storage pointer setting. The former can be a rather time consuming process, so care should be taken when choosing the download button. As the data is being downloaded from the monitoring site, the records will start to fill the Download Data screen. A box will appear to show the progress of this transaction. Once the process is complete, the number of records downloaded will be displayed at the top of the screen (Figure I-25). The data can be saved to a file, copied to the Windows clipboard for import into other programs, or downloaded to a graphing screen.

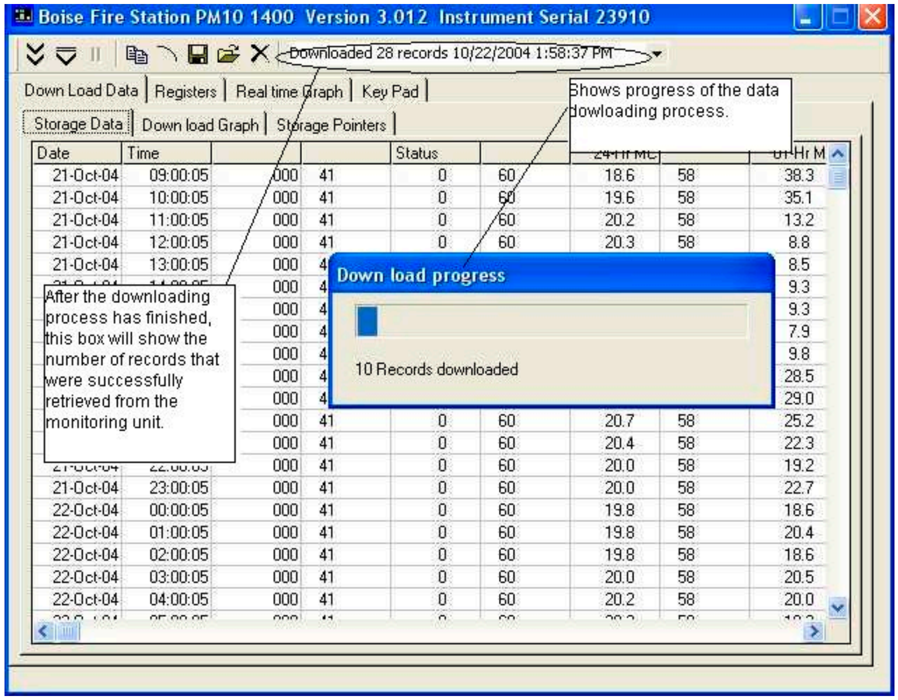


Figure I-25.Successfully Downloaded Data

Scheduling Automatic Data Downloads

With the automatic downloading capability of the RPComm software, a user can schedule data downloads from a monitor or list of monitors. It should be noted that prior to using this option, the State Office should be contacted to ensure that this process will not interfere with the automatic downloads taking place each day with the Data Acquisition System. To use the scheduling option, choose the 'Schedule Download' icon (Figure I-26) from the Connection List screen. This will bring up the Schedule Downloads screen (Figure I-27). From here, the user can choose or schedule the day(s) and time(s) for which the data will be automatically retrieved from the ambient monitoring unit.

Any combination of days may be selected. The user has the flexibility of choosing up to four downloading times per day. All of the data currently stored in the datalogger buffer can be downloaded by choosing the 'Down load all data' option. Otherwise, only the data saved in the datalogger after the last storage pointer setting will be downloaded each time by choosing the 'Down load from the storage pointer' option. Choosing the former will be more time consuming and may tie up communications with the monitor for a much longer time period. As a result, care should be used when creating an automatic download schedule to ensure that the correct data is downloaded each time.

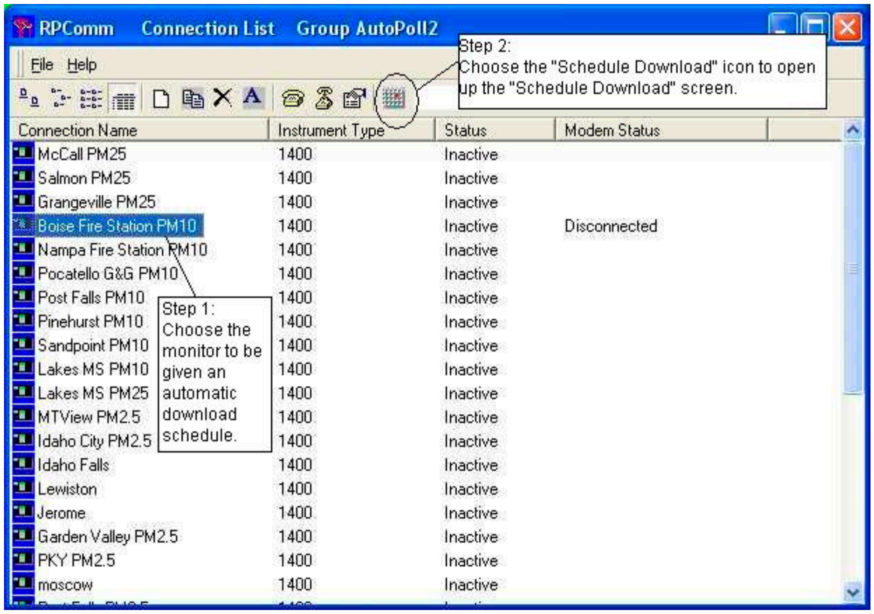


Figure I-26.Schedule Download Icon

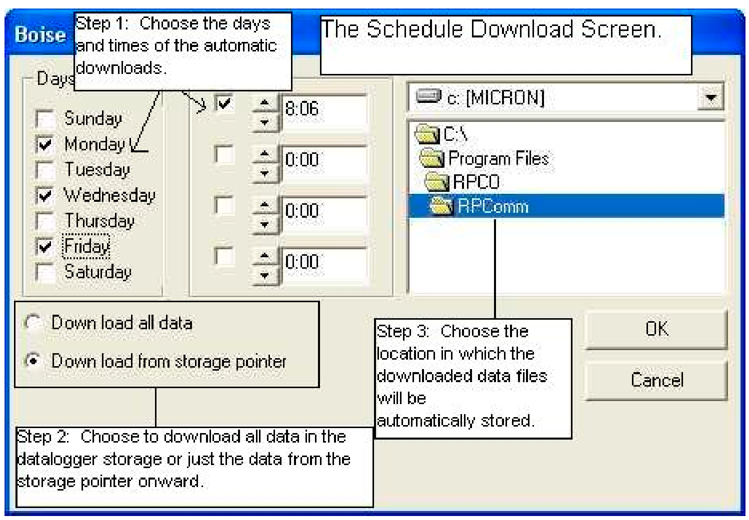


Figure I-27.Schedule Download Screen

Graphing Downloaded Data Using RPComm

While still in the Storage Data tab of the Download Data Screen, select the data values to be graphed. One way to do this is to place the cursor on the first data cell or record to be graphed. Using the left mouse button, drag the cursor down and across until all of the data of interest has been highlighted. Another way to select data is to click on a column heading, and while holding down the left mouse button, drag the cursor across all of the data columns to be graphed. This will automatically select all of the data within the highlighted columns. Once the data has been selected, use the graphing icon to send it to the graphing screen (Figure I-28). Choose the 'Download Graph' tab to look at the results. The key to the right of the screen shows the variables being graphed and their corresponding colors (Figure I-29). It should be noted that the scale of each axis and/or the number and type of variables being displayed, may need to be refined to enable easier viewing of the data.

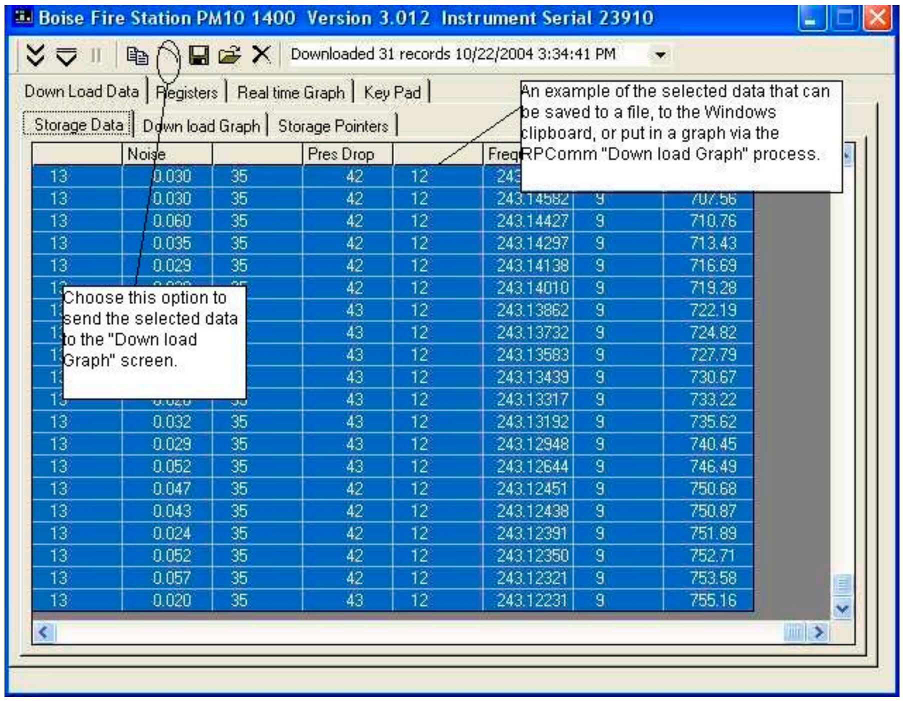


Figure I-28.Selected Data to be Graphed

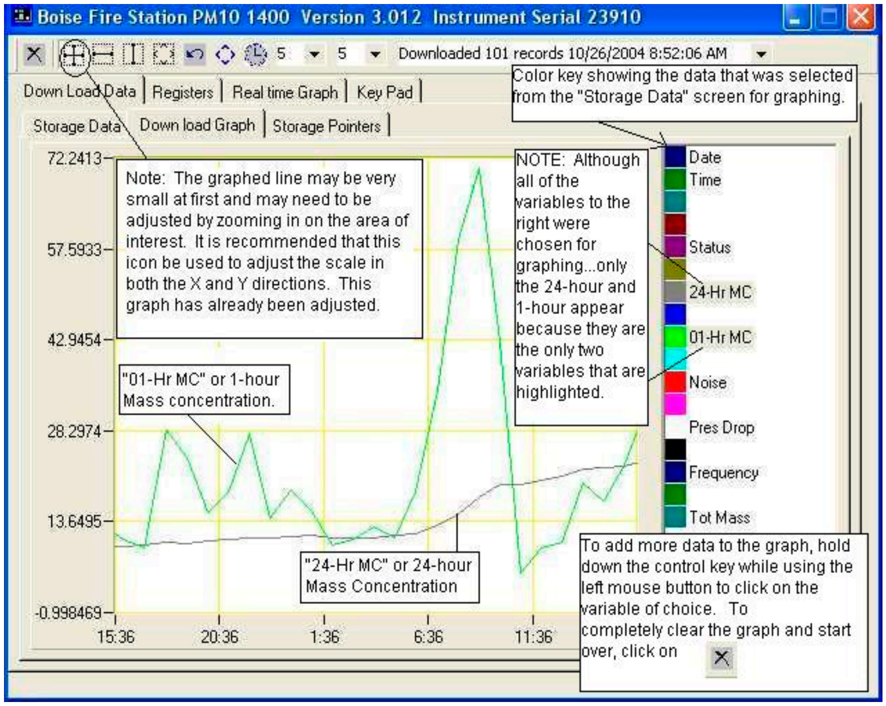
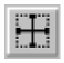


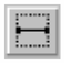
Figure I-29.Download Graph Tab

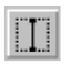
Figure I-30 provides an explanation of the various icons that are available on the toolbar of the graphing screen. These icons enable the user to modify the graph to obtain the best image possible. The user can adjust the scale of the axes by zooming in on a portion of the graph, in addition to defining the number of axis divisions and panning or moving the graphing area. The first of these functions is extremely important as it allows the user to tailor the graph to show the area or data of most concern to that user. To zoom in on a portion of the graph, select the appropriate icon to re-scale the x-axis, the y-axis or both at one time. Press and hold the left mouse button down while using the cursor to draw a box around the area of interest. Once the box is finished, release the mouse button and the graph will be resized to meet the dimensions specified. Continue zooming in on the area until the graph displays exactly the data needed.

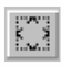
Although by default all of the data originally selected will appear on the graph, the user can employ certain built-in graphing options that will allow only certain variables to be displayed. To choose a variable to graph, either select the data directly from the Download Data screen or choose the variable from the color key code to the right of the graph. To choose more than one variable at a time, either select both variables as described in the previous paragraph or use the color key code exclusively. To choose more than one option from the color key code, click on the first variable and then hold the control key down while using the left mouse button to click on the second variable, and so on. By using this option, the graph is more manageable and allows the user to pick and choose which variables to compare. To display all of the data listed in the color key code again, click on the first variable and while holding down the shift key, select the last variable listed. To create a new graph, choose the icon that clears all of the data from the right-hand side of the graphing screen and go through the data selection process again.

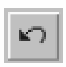

Clears all data listed on the right-hand side of the Download Graph screen. This includes the data being displayed.

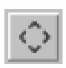

Decreases the scale of the x- and y-axes concurrently. With this icon selected, press and hold the left mouse button and make a box around an area (inside the graph) that you want to zoom into. Once the box is finished, release the mouse button. The graph will be resized according to the box dimensions.

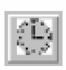

Decreases the scale of the x-axis. With this icon selected, press and hold the left mouse button at the beginning of the area that you want to zoom into. Drag the cursor horizontally to the end of the zoom area and release the mouse button. The graph will be resized according to the new x-axis dimensions.


Decreases the scale of the y-axis. With this icon selected, press and hold the left mouse button at the beginning of the area that you want to zoom into. Drag the cursor vertically to the end of the zoom area and release the mouse button. The graph will be resized according to the new y-axis dimensions.


Enables panning. Panning allows the user to move the graph area so that a different section of the x- or y-axis will be displayed without affecting the scale of either axis. With this icon selected, place the mouse cursor somewhere within the graph area and hold down the left mouse button. Move the mouse to display the desired section of the graph.


Selecting this icon will undo the last zoom or panning step.


Rescales the x- and y-axes so that all the graphs for the selected data are displayed.


Toggles between the two possible x-axis scales: date and time, and time only. This does not affect the way the data are displayed on the graph.

These two boxes define the number of axis divisions on the graph. The left box refers to the x axis and the right box refers to the y axis. The number of divisions on the axis can be set to 5, 10, 15 or 20. Increasing the number of divisions results in a finer axis grid. Decreasing the number of divisions results in a courser axis grid. This does not affect the way the data are displayed on the graph.

Figure I-30.List of Graphing Icons

In addition to graphing downloaded data, the user can utilize the Real Time Graph tab to look at the data of a register in real-time. Due to the frequency of the updates for this option, this graph may not prove to be as useful to the viewer as the previously discussed graphing routine. Therefore, this option will not be discussed in great detail in this document. To obtain more information on this graphing option, please consult Section 10.3 of the TEOM Operating Manual.

System Registers and the Virtual Keypad

It is recommended that instrument checks be carried out on a daily basis. Checking the system registers and instrument settings via the RPComm software and virtual keypad can be extremely useful in ensuring the proper function of a monitoring unit. By providing the operator with a remote means for checking a monitor's operation, potential problems may be caught earlier, resulting in improved data capture and decreased site visits. When checking the instrument, it is recommended that the current PRC or system register and current instrument setting be recorded in the site log. Any deviations from the expected results listed in Table I-3, should be investigated and may require an immediate on-site visit.

To view the system registers, select the 'Registers' tab from the Download Data screen. A list of all of the available system registers will appear on the right-hand side of the screen. To select a variable, click on the box next to it. A checkmark will appear to indicate that the register has been chosen for viewing. The user can choose to view as few or as many variables as he/she wants. As shown in Figure I-31, by choosing the 'Read Registers' icon, the user can see the most current values for each of the system registers that are checked. In addition, this list can be saved to a file to help the operator troubleshoot potential problems with the monitoring unit.

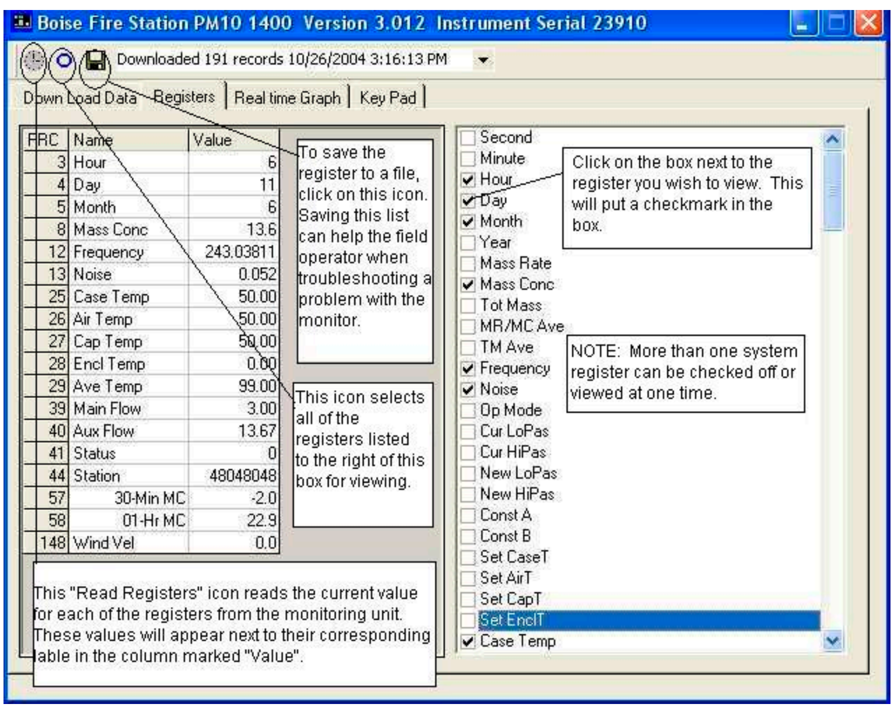


Figure I-31.Viewing the System Registers via RPComm

The Virtual Keypad

A virtual keypad is available in the RPComm software that looks exactly like the keypad on the front panel of the TEOM control unit. This keypad can be used to remotely access and modify the monitoring unit and is extremely convenient for making seasonal operating temperature changes, etc. All adjustable operating parameters can be changed via the keypad. The keypad is going to be used extensively when performing instrument maintenance and during weekly site visits. For more detailed information and guidance please refer to Sections 4 and 5 of the TEOM Operating Manual.

Viewing the Instrument Settings via the Virtual Keypad

To access the virtual keypad, select the 'Key Pad' tab while in the Download Data screen. As seen in Figure I-32, this keypad looks exactly like the one on the TEOM control unit. Press the 'Main Status' key. If the Main Status is already being displayed, then a status condition message of “No Curr Conditions” will appear. Pressing the 'Main Status' key again will bring up the Main Screen. The Main Screen in the upper left-hand corner of the Key Pad display shows the most current information regarding status, mass concentration, 30-minute average concentration and 1-hour average concentration. This information should be the same as what would be seen on the monitoring unit out in the field. If an "OK" does not appear on the first line (the status line), then that means that RPComm is not communicating with the unit properly. The potential reasons for this should be investigated.

The next number on the first line shows the operating mode. The number 4 indicates that the unit is fully operational and that all mass values are being calculated. This is the mode in which the unit normally resides. A letter S indicates that the unit is in the setup mode. Although the monitor is continuing to collect a sample flow and maintain set operational temperatures, it is not collecting any data. Operating parameters, such as the temperature and flow, can only be changed in this mode so as to not affect the data collected. To enter this mode, press the 'Data Stop' key. To leave this mode, press either the 'F1' or 'Run' key.

The status line also shows the percent loading on the filter. This reading is important because it gives the operator a good indication of when to change the TEOM filter. The filter cartridges should be changed before a filter loading of 100% is reached. At some point above this, the main flow can drop off below its set point. This may in turn raise questions as to the validity of the data being collected by the monitor. A new filter should show readings of 15% to 30% at a main flow rate of 3 lpm. If the filter loading is greater than 30% or if the lifetime of the filter cartridges decreases at a faster rate than expected, the in-line filter of the main flow line should be inspected and replaced if necessary.

Also in Figure I-30, the status line shows the level of security set for the monitor. The letter U indicates that the monitor is in an unlocked mode. The user has access to all of the monitor’s capabilities. The letter L indicates that the monitor is in low lock mode. The user is prevented from editing any of the systems settings, but may view these settings and change the operating mode of the instrument to carry out certain maintenance procedures such as filter changes. The letter H indicates that the monitor is in high lock mode. The user cannot make any changes to the instrument other than turning off this mode with the appropriate password. The last bit of information contained on the status line is the current time. For more information on the status line, please refer to Section 4.2.1 of the TEOM Operating Manual.

The virtual keypad can be used in the same manner as the keypad on the actual monitoring unit. Although the mass concentration, 30-minute and 1-hour average mass concentrations will appear by default, the user can use the down arrow key to view other pieces of information -- including the 24-hour average mass concentration and various temperature and flow readings. Since the Main Screen shows the most current data being collected or computed by the monitoring unit, the values cannot be changed by the user.

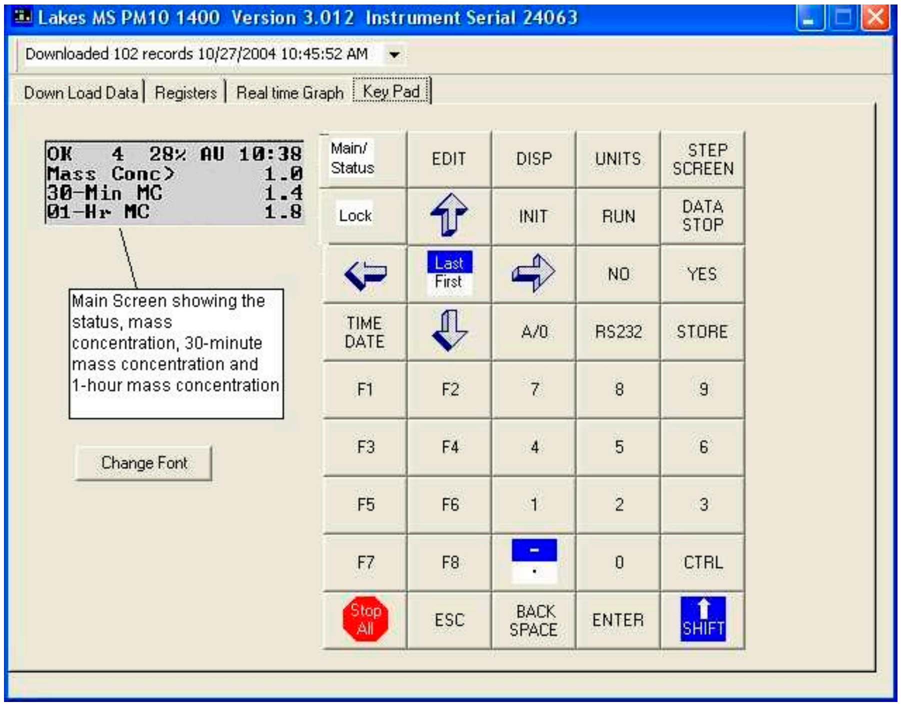


Figure I-32.Keypad Screen

Changing the Instrument Settings via the Virtual Keypad

Normally the monitor is in the Display or Browse mode. This allows the user to move from screen to screen to view the monitoring unit's settings or operating conditions. In certain cases, however, the operating parameters may need to be changed. An example of this is the seasonal variation in the air, cap, case and enclosure temperature settings. As previously mentioned, the virtual keypad of the RPComm software provides a convenient tool for making these changes remotely via a modem connection. Whenever such a change is required, it is recommended that the procedure be carried out at the beginning of the day. This provides the operator with time throughout the day to check the monitor's status and to identify any problems associated with the parameter revisions that might lead to lost or invalid data.

The TEOM utilizes menu-driven software that can be accessed via the keypad. This allows the user to access the various set-up screens directly or indirectly through the Menu Screen. To get into the Menu Screen, press the 'Step Screen' key. The status line will be replaced by the heading 'Listing of Screens'. Use the down and up arrows to maneuver around the menu to choose a screen to either view or revise. From the Menu Screen, the user can go to the Set Temps/Flows or Set Time screens to carry out some of the more basic modifications to the TEOM monitor. Although the TEOM Operating Manual describes these processes in more detail, a few of the more basic keypad routines are provided below.

Changing the TEOM Date and Time Settings

Idaho straddles two time zones - the Pacific and Mountain Time zones. The TEOMs will always be set on standard time and WILL NOT be set on daylight savings time. The TEOM clock should be checked periodically via the RPComm software or during every site visit. Do not allow the clock to drift by more than ± 15 minutes from the standard time. If the clock is found to be off by more than 15 minutes, the user can reset the values using the Set Time screen. In addition, the user may use this option to reset the date if needed.

Although this screen may be accessed via the Menu Screen described in the previous sections of this document, the easiest way in which to access this option is through the 'Time Date' key located directly on the keypad. It should be noted that the time and date can only be changed when the instrument is in the Setup Mode. To enter this mode, press the 'Data Stop' key. The line below the Set Time header contains the current time and date generated by the monitor's internal clock/calendar. To change a parameter, use the down and up arrow keys to scroll to the variable to be changed. Use the 'Edit' key to put the monitor into edit mode - a question mark will appear on the screen in place of the cursor. Edit or revise the system parameter and then press enter to save this change. Each time a new entry is made, the instrument will automatically change the seconds counter to 00. It should be noted that when changing the Month setting, January is month zero and December is month 11. The escape (Esc) key can be used at any time to exit the editing mode. Press 'Run' to restart the data collection mode. For more information on the editing mode, refer to Section 4.3.4 of the TEOM Operating Manual.

Changing the TEOM Temperature and Flow Settings

DEQ may change the operational temperature set points twice a year to account for seasonal variations in airstream temperatures. These changes are made to help reduce the volatilization of light hydrocarbon compounds on the filter in an effort to provide a better correlation of the TEOM data with conventional gravimetric particulate measurements. For more information on the reasons for these changes, please refer to R&P's Technical Note No. 4, dated October 1993.

While in general the airstream temperatures between October 1 and March 31 differ from those between April 1 and September 30, field operators often rely upon the TEOM concentration and status code readings to "tell" them when the temperature settings need to be revised. If the status code of 2 -- for temperature(s) outside of the operational bounds -- and a corresponding wide range of variability in the particulate concentration readings show up each day, it is usually an indication that the temperature settings may need to be revised. Though these changes are usually needed during the transitional months of spring and fall, they may not always occur during the same time of the year for each monitor. In addition, there may be times when they are not found to be necessary at all. Although the usual temperature settings are listed by season in Table I-3, some operators have found that a temperature setting of 40 rather than 30 degrees is more appropriate for their region(s) during the winter months.

Table I-3.Recommended Idaho TEOM - Seasonal Temperature Set-Points

	PRC	OCT 1 - MAR 31 SETTING	APR 1- SEPT 30 SETTING
CASE Temperature	021	30.00 (or 40)	50.00
AIR Temperature	022	30.00 (or 40)	50.00
CAP Temperature	023	0.00	50.00
ENCLOSURE Temperature	024	25.00	40.00

The user can review and change the temperature and flow rate settings from the Set Temps/Flows screen. Use the 'Step Screen' key to enter the Menu Screen as described in previous sections of this document. Choose the 'Set Temps/Flows' option. Each temperature and flow rate has two sets of numbers associated with it. The first value is the parameter setting and is the value that can be changed. The second value is the most current reading and cannot be changed. Scroll to the parameter to be changed using the up and down arrow keys. Press 'Data Stop' to enter the Setup Mode and then choose 'Edit' to change the value. After revising the numerical value, press 'Enter' to save the changes and 'Run' to restart the data collection process.

As mentioned previously, it is recommended that temperature revisions be carried out as early in the day, and prior to the start of a new hour, as possible to allow for continued monitoring of the monitoring unit’s responses to these changes. If a problem is found as a result of these changes, then the problem should be investigated as soon as possible to prevent a significant loss of data.

The IDEQ 1400AB TEOMs are equipped with ambient temperature and pressure sensors and self-compensating flow controllers. As a result, the average temperature and pressure settings used in the flow calculations (PRC #s 029 and 031) DO NOT need to be changed. However, they DO need to be initially fixed to the manufacturer-recommended settings listed in Table I-3.

Table I-3. R&P Provided PRC Set-Points

PRC	Description	Setting
029	Average Temperature, used in flow calculations	99
031	Average Pressure, used in flow calculations	9

The monitoring unit uses the parameters on the Set Temps/Flows screen to determine the reporting units of the measured mass concentration levels. If the user chooses to set the unit to report the mass concentration levels at actual conditions, both the average and standard temperatures must be set to "99" and both the average and standard pressures must be set to "9". These are the appropriate settings for $PM_{2.5}$ data collection. NOTE: If the user wants to use the instrument for US EPA equivalent PM_{10} measurements, the standard temperature MUST be set to 25° C, and the standard pressure MUST be set to 1 atm regardless of the values entered into the system for the average temperature and pressure. For more detailed information on the various temperature settings and their effects on the flow rate calculations, please refer to Section 6.3 of the TEOM Operating Manual.

All revisions to the monitor or its settings, whether carried out remotely via the modem or during an actual site visit, MUST be recorded in the appropriate site log for each monitor. It is extremely important that these activities be recorded from a quality assurance standpoint to help ensure the validity of the data. If any questions regarding these maintenance steps arise, the DEQ State Office should be contacted immediately.

Storing the Downloaded Data to a File

To store the downloaded data to a file, make sure that you have the 'Storage Data' tab selected. Choose the 'Save All Displayed Data to a File' icon at the top of the Download Data screen (Figure I-33). This will bring up the Save Dialog box, prompting the user for a file name. As shown in Figure I-34, the default file name format is XXXXXYzz.txt, where XXXXX is the serial number that is unique to that monitor, Y is the data type (S for storage), and zz is the file number. To give the file a different name, type over the default name provided and then hit 'Save'. The file will be automatically saved as a comma-delimited ASCII text file which can be easily opened using a common word-processor or imported into a spreadsheet program such as excel.

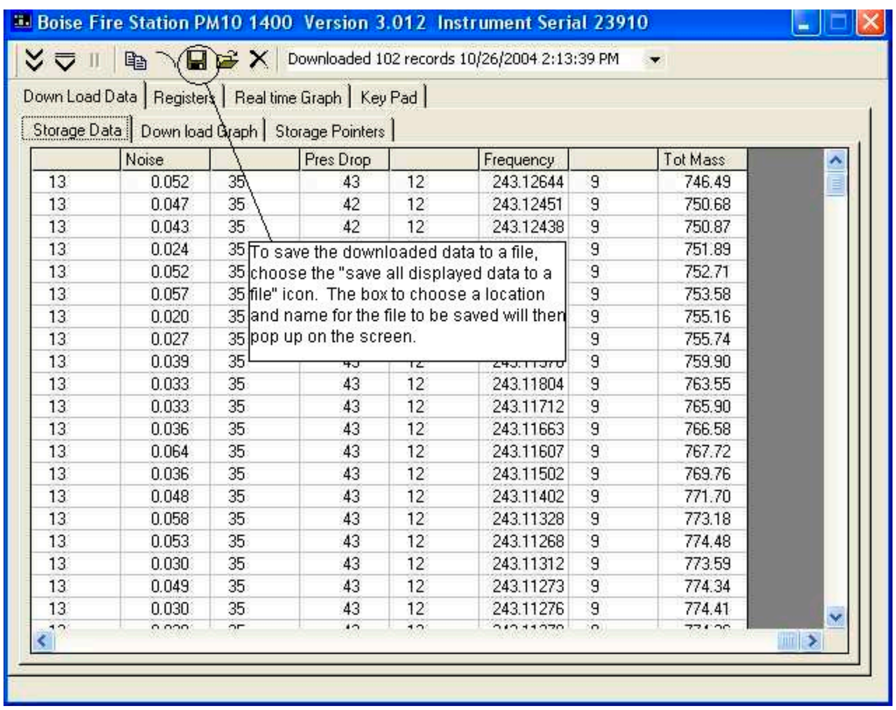


Figure I-33.Save Data to a File Icon

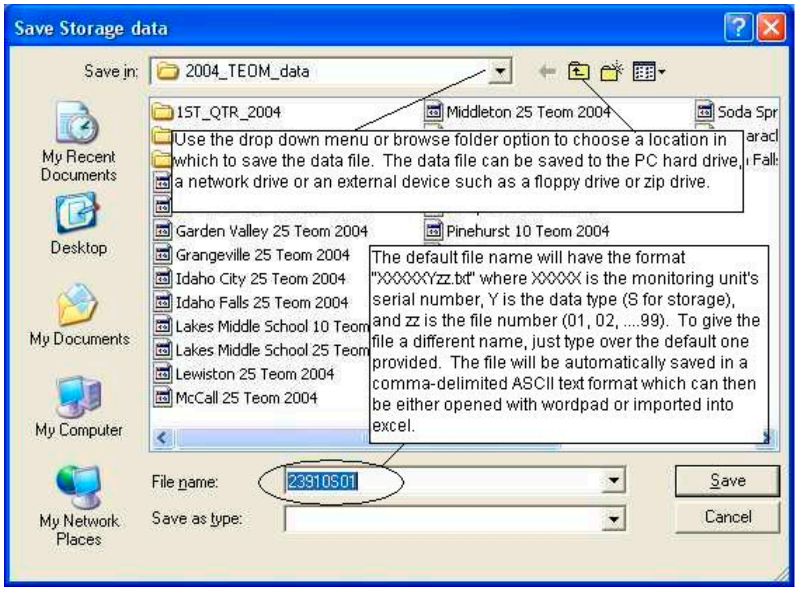


Figure I-34.Save Dialog Box

I.3.2 SAMPLE FILTER INSTALLATION AND EXCHANGE

The TEOM must always be operated with a sensor filter cartridge (available only from R&P) installed in the mass transducer. Upon installation of the TEOM, install a filter cartridge as described in Section 3.1 of the R&P TEOM manual before supplying power to the instrument.

TEOM filter cartridges must be exchanged before the status line on the Main Screen for *Filter %* loading reaches 100%. As a warning, the **Check Status** light turns on when the filter loading is greater than 90%. In addition, the status code "8" will show up in the data string to warn the operator of the potential need for a filter change. The average filter lifetime depends on ambient particulate concentrations, but is typically two to six weeks.

a. When removing an old filter and replacing it with a new one, first push *Data Stop* on the keypad to make sure the instrument is in the Setup Mode.

b. Using the filter exchange tool provided with the instrument, gently lift the old filter from the tapered element with a straight pull. **DO NOT twist the filter**.

c. Using the filter exchange tool, place a new filter on the tapered element with slight downward pressure. **DO NOT twist the filter and DO NOT handle the TEOM filter cartridges with your fingers**.

d. Slowly close the mass transducer. The unit is spring loaded so do not slam shut.

e. Close and latch the door to the TEOM sensor unit.

f. Press *F1* or *Run* to re-start data collection.

g. Check the frequency on the Main Screen to make sure it is operating within the normal operating parameters and that the numbers to the right of the decimal point are not fluctuating rapidly. Every mass transducer oscillates at a different frequency, but generally ranges between 150 and 400 Hz.

h. Record the time and date of the filter exchange in the site log book.

I.3.3 EDITING HARDWARE PARAMETERS

The editing of most operational parameters can be done using the keypad or the TEOMCOMM software. Modem communication involves the use of manufacturer-assigned PRCs. The complete inventory of PRC codes are listed in Appendix A of the R&P Manual.

I.3.3.1 OPERATION AFTER A POWER FAILURE

All TEOM operating parameters including the clock and calendar are maintained in a battery backed-up memory. Upon regaining power, the instrument waits for temperatures and flow rates to remain stable for one-half hour before automatically resuming data evaluation. A cursory inspection of monitoring hardware and associated peripherals should be performed following a power outage. The inspection will help to determine if any damage was sustained to the monitor, modem, or other components. The operator should also check that system installation is not to blame for the power problems.

I.3.3.2 LOG BOOK REQUIREMENTS

All DEQ TEOM data reporting stations are required to maintain site-specific instrument log books. The log book(s) should be hardbound, with numbered pages. It will be used as an official record for documenting all TEOM maintenance activities, quality control checks, site visits, and data transfers. The following is the minimum required log book documentation:

a. Site visits.
   1. Date, TEOM time, and actual time
   2. Status condition and operating mode
   3. Filter loading (%)
   4. Main and auxiliary flows
   5. Noise and frequency
   6. Mass concentration (at minimum the instantaneous value)
   7. Enclosure temperature
   8. Operator's initials

b. Maintenance and Quality Control (QC) checks (including precision checks)
   1. Activities
   2. Results of checks, etc.
   3. Operators initials

c. Data transfer
   1. Activities
   2. Operator's initials

d. Remote modifications via modem (including precision checks)
   1. Recorded on Daily Modem Update Sheet

I.3.4 DATA HANDLING

DEQ State Office staff in Boise poll the data stored by the TEOMs' internal data loggers approximately every week using the latest version of RPComm software (version 1.6.61 for

Windows 9x/NT/2000) provided by Rupprecht and Patashnick (R&P). This data is stored as an ASCII file in the AQ Monitoring\XXXX_TEOM_data location on the shared drive (the XXXX stands for the data year). Each of the archived files is given a name indicating the location and type of monitor being stored. The following is an example of the preferred format for data storage in the data logger:

01-Jan-02,00:00:05,NNC, 41, 0, 60, 3.1, 58, 5.1, 13, 0.061, 35, 56, 12, 262.594, 9, 74.58
01-Jan-02,01:00:05,NNC, 41, 0, 60, 3.6, 58, 9.1, 13, 0.060, 35, 57, 12, 262.594, 9, 74.80

where the data string contains the following information: date, time, three-letter station identifier, PRC 41 for status, status, PRC 60 for 24-hour average concentration, 24-hour value in $\mu g/m^3$, PRC 58 for 1-hour average concentration, 1-hour value in $\mu g/m^3$, PRC 13 for noise, noise level, PRC 35 for filter loading or percent of filter lifetime used, percent loading, PRC 12 for frequency, frequency reading, PRC 9 for total mass loading on the filter, and total mass in grams.

The data is checked for status codes, elevated noise, etc. If potential problems are found, the regional office will be notified to help resolve the issues. Ambient air monitoring data, including TEOM data, are also being polled by the data acquisition system (DAS) or Central Data Management System (EMC System Manager 2). The DAS has been set up to acquire $PM_{2.5}$ TEOM data on an hourly basis and PM_{10} TEOM data on a daily basis. The DAS will eventually be used as the primary polling system and main storage area for all DEQ data and has been designed to allow for the QA, editing, and preparation of data for submittal to AQS.

It is recommended that the regional offices also download and archive their data on a regular basis. Not only does this allow for decreased risk of lost data, but also allows for the regions to identify and fix potential instrument malfunctions before data validity comes into question.

I.3.5 DATA REVIEW AND VALIDATION REQUIREMENTS

Using the archived files mentioned in the previous section, the quarterly data for each TEOM is broken out by the second month of the following quarter. Prior to State Office review, the regional offices are asked to update the site log for each monitor in their region. The quarterly data files are then reviewed to determine if any data records are missing. If missing data are identified, State Office staff will try to determine the reason. This involves review of the appropriate site log for each monitor and, if needed, State Office staff will ask each regional office for copies of the data in question. The goal is to ensure the data files are as complete as possible during the QA process and missing data are associated with the appropriate null code prior to submittal to EPA. If a large subset of data is missing, the TEOM processing software can be used to build missing data with the appropriate null code.

Once missing data have been identified and/or filled in, the file is imported into Excel where the filtering option identifies records associated with a status code greater than zero or records with an hourly value of zero. Each data filter created in Excel is printed and kept for future record.

Hourly values of zero are checked to ensure they are not a reflection of a data stop caused by user interaction (maintenance) or a power failure. Any data interruptions identified during this process are reconciled with the appropriate site log located on the shared drive under AQ Monitoring\SiteLogs. Since the TEOM uses an oscillating element, vibrations from air conditioning units or nearby traffic can cause fluctuations in the data that may result in negative hourly concentration values. In such instances, it is DEQ policy that any datum less than –5 $\mu g/m^3$ be null coded with a 9979 (miscellaneous void), any datum greater than or equal to –5 $\mu g/m^3$ but less than 0 $\mu g/m^3$ is changed to 2.5 $\mu g/m^3$, and any value greater than or equal to zero is left as is prior to submittal to AQS. The TEOM processing software has been designed to deal with these situations.

A code indicates the status of the TEOM at the time of operation. A status code of zero indicates the machine was running within optimal operating conditions at the time that the data record was stored. The following is a list of additional status codes that may be recorded:

1 = Frequency signal failure (the control unit is not receiving a frequency signal)
2 = Temperature(s) outside of operational bounds - the range is ±0.5° C for the air temperature, and ±0.1° C for the cap and case temperature
4 = Flow(s) outside of operational bounds - the range is ±0.1 l/min. (this could indicate potential pump related problems)
8 = Filter loading is at 90% or above (warning flag to signify the need for a filter change)
12 = Combination of an 8 and 4 (for example) - filter loading has reached a point where the flow is starting to be affected

Hourly data values associated with codes 1, 4, or 12 will be invalidated with the appropriate null code prior to submittal. Values associated with the temperature status code will be evaluated to determine their validity.

Finally, anomalous looking data are further evaluated prior to submittal using the available site log information, discussions with the appropriate regional office staff, available weather information, and news media information regarding events such as forest fires. Once the data review is complete, the quarterly data file is imported into the TEOM processing program where most of the null codes will be assigned. The data is then exported as an AQS-formatted file and any final null codes are manually entered. Data found to be reasonable based upon the aforementioned review are submitted to the EPA database as final.

As part of DEQ’s Air Quality Index (AQI) program, each regional office is required to evaluate their air quality data (including the TEOM data) on a daily basis using either the DAS or RPComm software. The regions should review their data, determine the AQI, formulate an AQI forecast, and update the appropriate air quality Web pages as needed. As a result of this activity, each region is carrying out an internal daily QA that will help to reduce the loss of valid data.

I.3.6 SPECIAL DATA HANDLING ISSUES

Since the TEOM operates using an oscillating element, it tends to be sensitive to vibrations. Vibration from nearby traffic, roof fans, or other sources can cause aberrant fluctuations in the data. Because of this, the data printouts will often show negative numbers. The AQS database will not accept negative particulate concentrations, so the negative numbers must be corrected, or flagged. The minimum detectable limit of the TEOM is less than five micrograms/cubic meter. Please refer to Section I.3.5 of this document for more detailed instructions regarding the QA of negative hourly TEOM values.

I.3.7 DATA ASSESSMENT

At all DEQ TEOM sites where there exists a collocated $PM_{2.5}$ federal reference monitor, linear regression analyses will be performed to determine equivalent vs. reference methods comparability and to assess TEOM data quality. Central office personnel will perform the regressions monthly, quarterly, and annually for data spanning the calendar year.

A regression will be setup where the independent (x) variable is the 24 hour average TEOM data, and the dependent (y) variable is the federal reference monitor data. The r^2 value should be noted. With this same set of data, concentration differences, percent differences, and a correlation coefficient should be calculated. Anomalous data points must be investigated for validity by the TEOM operator.

I.4 MAINTENANCE

Routine service will be performed at specified intervals. Troubleshooting monitor malfunctions or unusual operating parameters will be performed as needed. Requirements for maintenance are usually site specific and vary from one location to another. Users should be familiar with Appendices C-F and Section 12 of the R&P Manual before attempting any maintenance of a TEOM monitor.

I.4.1 REGULAR INSPECTIONS AND MAINTENANCE

Perform the following regular inspection and maintenance operations on a <u>monthly</u> basis, unless directed to perform them more frequently, to retain the equipment's ability to provide quality data. Some of these inspections will not generate maintenance activities each month, but early detection and rectification of potential problem areas will yield high quality operations, less lost data, and more equipment operating time. As with any schedule the frequency will vary slightly due to local sampling conditions.

I.4.1.1 CLEANING THE INLET

If needed, clean the impaction plate and accelerator assembly of the inlet as follows:

a. Carefully remove the PM_{10} or $PM_{2.5}$ inlet assembly from the inlet tube.

b. Separate the collector assembly from the accelerator assembly.

c. Clean the impaction plate (collector) using a general purpose cleaner. Clean the bottom, walls, and three vent tubes of collector.

d. Dismantle the top plate from the accelerator assembly and remove the insect screen.

e. Clean the accelerator tube using a general purpose cleaner.

f. Reassemble the screen and the top plate and re-install them onto the collector assembly.

g. Carefully replace the PM_{10} or $PM_{2.5}$ inlet assembly on inlet tube.

I.4.1.2 REPLACE IN-LINE PARTICULATE FILTERS

It is critical for proper operation that the Mass Flow Controllers (MFCs), located inside the TEOM control unit, remain free of particulate contamination. This is done by replacing the in-line particulate filters when they show signs of becoming loaded with particles. The in-line filters must be replaced before the filters become plugged, preventing adequate flows. In most circumstances this corresponds to an exchange every six months, however, local conditions will determine this schedule.

a. Press *data stop* to take the TEOM offline.

b. Remove the vacuum pump source from rear of the TEOM.

c. Remove the large bypass line filter or the two small filters on the rear panel of the TEOM.

d. Replace the old filter(s) with the new filter(s), installing them with the arrow on the filter(s) pointing against the direction of flow. (This is done to aid in the determination of a fully loaded filter).

e. Replace the vacuum line.

f. Reset the TEOM to run.

g. Perform a systems leak test after connecting the new filters into the flow lines.

I.4.1.3 VACUUM PUMP CHECK

The TEOM requires a minimum vacuum pressure to operate properly. Checking it periodically will help to identify a problem before large blocks of data are invalidated.

a. Press *data stop* to take the TEOM offline.

b. Disconnect the vacuum line.

c. Install a portable vacuum pressure gage in the vacuum line.

d. Record the vacuum (usually in inches of mercury) reading in the site log book.

e. Remove the vacuum gauge and re-connect the vacuum line.

f. Reset the TEOM to run mode.

When the pump vacuum falls below 20 inches of mercury (in-Hg) and /or cannot maintain a consistent flow rate, repair or replacement of the pump is necessary.

I.4.2 MAIN AND AUXILIARY FLOW SYSTEM CHECKS

Maintaining the correct flow rates through the system is essential to the proper operation of the TEOM and the subsequent determination of particulate concentrations. EPA guidance states that on-site precision checks of the analyzer's normal flow rate must be completed by the operator <u>every two weeks</u>.

I.4.2.1 PRECISION CHECKS AND AUDITS

Flow checks are used to assess precision. Standard procedures for precision checks are described in Section I.4.2.1.1 below. These precision checks must be completed every two weeks on each TEOM. If the TEOM is audited at least every six months and records of the three most recent flow audits confirm the flow meter is stable, reliable, and accurate to ± 4% with no indication of improper operation, the on-site precision check can be skipped and flow can be checked by remotely dialing into the monitor. Should the TEOM have a major component replaced, need any portion sent in for calibration, have poor flow readings, or be moved to a new location, the on-site precision checks must be done every two weeks until three audits confirm the flow meter is again stable and reliable.

An independent performance audit of a TEOM's flow rate is required at least once annually. DEQ performs flow audits on a quarterly schedule. Refer to Section I.6 below on TEOM Audits and Section 5.3 of the R&P Manual for the complete audit instructions.

I.4.2.1.1 System Flow Check

The following steps are taken at the site every two weeks during precision flow checks (unless the audit results described in Section I.4.2.1 are met) and during quarterly performance audits:

a. Press *data stop* to take the TEOM offline.

b. Remove the PM_{10} or $PM_{2.5}$ inlet from the inlet tube and install the reference flow device adapter to the TEOM inlet tube.

c. Connect the reference flow device to the adapter and take a measurement of the flowrate. Measuring the flowrate at this configuration determines the reference device flowrate for ***total flow*** of TEOM system. The total flow should be 16.67 lpm ±10%.

d. Remove the auxiliary flow line (the green tube) at the flow splitter and fasten the compression cap to seal the splitter connection.

e. Determine reference device flow for main (sample) flow of TEOM system. The sample flow should be 3.0 lpm ±10%.

f. Calculate auxiliary flow rate from two flows obtained in steps 4 and 6.

g. Calculate the percent difference of the TEOM displayed flows to the reference displayed flows and record in site logbook.

QC Difference = Sampler Displayed - Actual Transfer Standard / Actual Transfer Standard x 100

h. Reconnect the auxiliary flow line to the flow splitter.

i. Remove the flow adapter and replace the PM_{10} or $PM_{2.5}$ inlet.

I.4.2.2 LEAK TEST

On a quarterly basis, and after performing any maintenance activity that involves the removal and reconnection of the flow system hoses, a leak check is necessary. If no maintenance involving hose disconnection is conducted during a quarter it is recommended that a leak check be performed during the flow check. Refer to Section 3.4 in the R&P Manual for complete instruction.

a. Place the TEOM in the data stop mode.

b. Remove the PM_{10} or $PM_{2.5}$ inlet assembly from the inlet tube.

c. Install the reference flow device (RFD) adapter to the TEOM inlet tube.

d. Slowly close the adapter petcock until all flow is stopped.

e. Check the TEOM display. As you watch the display, you should notice the flowrate dropping close to or less than zero, which indicates an airtight system. If the flow rates do not drop close to or less than zero the operator will have to troubleshoot to identify the leak (if the TEOM display indicates an auxiliary flow rate of greater than 0.65 actual lpm, or a main flow rate of greater than 0.15 actual lpm, then check for leaks).

f. SLOWLY open the flow adaptor petcock to prevent sensor filter damage, until the flow is restored.

CAUTION: Opening the flow adapter too quickly could damage the filter.

g. Remove the flow adapter and replace the inlet assembly.

I.4.3 SEMI-ANNUAL MAINTENANCE

The scheduled maintenance items listed below are required on a semi-annual basis for the proper operation of the TEOM. As with any schedule, the frequency will vary slightly due to local sampling conditions. Relatively dirty airsheds will require more frequent maintenance activities than relatively clean airsheds.

I.4.3.1 CLEANING THE AIR INLET SYSTEM

The inlet system is susceptible to particulate buildup on the inner walls of the inlet tube. The manufacturer recommends cleaning the inlet tube twice a year. Refer to Section 7.5 in the R&P manual for complete instructions.

a. Turn off the control unit

b. Remove the air thermistor from the cap

c. Pivot the microbalance into its open position

d. Protect the mass transducer with plastic wrap or other protective material

e. Using mildly soapy water and a soft brush, clean air inlet inner walls

f. Allow inlet to dry

g. Remove the plastic wrap protection from microbalance and return the microbalance to its closed position

h. Re-insert the thermistor

i. Turn on the control unit

I.4.3.2 MASS FLOW CONTROLLER(S) CALIBRATION (SOFTWARE)

Calibration of the mass flow controllers can be accomplished simply without having to adjust any hardware. The software procedures allow the user to calibrate with the touch pad interface. Refer to Appendix J, Section 2 in the R&P Manual for complete instruction.

a. Turn off the control unit

b. Disconnect the electrical cable that links the control unit to the mass transducer

c. Turn on the control unit

d. Select Set Temps/Flows screen and scroll to F-Aux and F-Main, record the set points for the main and auxiliary flows

e. Scroll to T-A/S P-A/S and record the existing values, then set them to current conditions

f. Scroll to F-adj Aux and F-adj Main

g. Attach a reference flow meter to the Sensor Flow location on the back of control unit

h. Compare the value of the reference flow meter to the TEOM value; edit the value of F-adj Main until the flow shown on the reference flow meter match those recorded in step d

I. Repeat steps g and h using the port marked Auxiliary Flow on the back of the control unit

i. Return T-A/S and P-A/S to the original values recorded in step e

j. Turn off the control unit

k. Make sure the air lines are re-inserted into proper locations at the back of the control unit

l. Re-connect the electrical cable that links the control unit to the mass transducer

m. Turn on the control unit

I.4.4 ANNUAL MAINTENANCE

The scheduled maintenance items listed in this section are required on an annual basis for the proper operation of the TEOM. As with any schedule, the frequency will vary slightly due to local sampling conditions.

I.4.4.1 CALIBRATION (HARDWARE) OF MASS FLOW CONTROLLER(S)

The TEOM comes equipped with either a Brooks flow control system or a Tylan flow control system. Both mass flow controllers (MFC) are easily calibrated using certified flow transfer standards equipment. The following procedures are generic. Refer to Appendix J, Section 3 in the R&P Manual for complete instruction.

a. Turn off the control unit

b. Disconnect the electrical cable that links the control unit to the mass transducer

c. Remove the top cover of the control unit

d. Position the MFC bracket for easy access

e. Turn on the control unit

f. Scroll to T-A/S P-A/S and record the existing values, then set them to current conditions

g. Ensure that the software flow adjustments are set to 1.00

h. Attach the reference flow meter to the Sensor Flow location on the back of the control unit

i. Close off the vacuum source to stop all flow to the MFC

j. Adjust the zero potentiometer on the main flow MFC until a zero reading is shown on the TEOM display

k. Set the flow set-point to full scale of the MFC (should be 5 lpm)

l. Open the vacuum pump source to allow complete air flow

m. Adjust the gain potentiometer on the main flow MFC until a full-scale reading is shown on the TEOM display

n. Repeat steps i-m until both the zero and the full scale value are correct without further adjustments.

o. Repeat steps h-n using the Auxiliary Flow port and the MFC

p. Return T-A/S and P-A/S to the original values recorded in step f

q. Turn off the control unit

r. Make sure the air lines are re-inserted into the proper locations at back of the control unit

s. Re-connect the electrical cable that links the control unit to the mass transducer

t. Turn on the control unit

I.4.4.2 ANALOG CALIBRATION

R&P suggest an annual calibration of the analog input/output. It is further recommended that this procedure be completed prior to the mass flow calibration. Given the complexity of calibrating the analog input and outputs and the limited scope of this QA document, refer to Section 1.2 in the R&P Manual for complete instruction.

I.4.4.3 MASS TRANSDUCER CALIBRATION VERIFICATION

The DEQ does not at this time employ the procedure of mass transducer calibration verification. According to the manufacturer, using the TEOM under normal circumstances the calibration does not change materially over the life of the instrument.

I.5 MISCELLANEOUS ITEMS

I.5.1 SPARE PARTS AND EQUIPMENT ON HAND

The following is a recommended list of spare parts and equipment that the operator should have on hand to perform as needed repairs and maintenance activities:

- 1 vacuum pump motor
- 1 vacuum pump motor rebuild kit
- 2 large in line particle filters
- 4 small in line particle filters (if used)
- 1 box sensor filters
- 10 feet auxiliary and main flow line
- 1 bottle cleaning solution
- 1 box lint free wipes or similar towels
- 1 small brush

I.5.2 RECOMMENDED TOOLS AND EQUIPMENT

The following is a recommended list of tools and equipment that the operator should have on hand to perform as needed repairs and maintenance activities:

- Digital multi-meter
- Flow calibrator or similar flow-measuring device
- Temperature and pressure indicators
- Calculator
- Various hand tools (screwdrivers, wrenches, small sizes, etc.)
- R&P TEOM operating manual
- Inlet flow adapter
- Gun-cleaning kit, or other suitable brush, for sample line cleaning

I.6 TEOM AUDITS

I.6.1 OBJECTIVES AND GUIDELINES

The audit procedures described in this section outline the steps for implementing a performance audit for the Rupprecht and Patashnick Series 1400AB TEOM PM_{10} monitor operated in the state of Idaho by DEQ. The primary objective of an auditing program is to identify system errors that may result in suspect or invalid data. A true assessment of the accuracy of a PM_{10} measurement system can only be achieved by conducting an audit under the following guidelines:

a. Without special preparation or adjustment of the system to be audited.

b. By an individual with a thorough knowledge of the instrument or process being evaluated, but not by the site operator.

c. With accurate, calibrated National Institute of Standards and Technology (NIST) -traceable transfer standards that are completely independent of those used for routine calibration and QC checks.

d. With complete documentation of audit information for submission to the operating agency. The audit information includes, but is not limited to, types of instruments and audit transfer standards, instrument model and serial numbers, transfer standard traceability, calibration information, and collected audit data.

e. Two instrument flow rates are challenged with a calibrated transfer standard volumetric flow meter. The actual instrument flow rate (nominally 3 lpm) is measured with the transfer standard and reported for accuracy. The total flow rate is also checked to verify that it is within the ±10 % tolerance specified for the PM_{10} inlet, but total flow rates are not reported for accuracy. The instrument clock is checked to verify it is within ±15 minutes of Standard Time. The temperature sensor is challenged with a NIST traceable thermometer to verify it is within ±2 °C. The pressure sensor is challenged with a NIST traceable barometer to verify it is within ±10 in Hg of the audit measurement.

Definitive procedures are not established for the use of calibration foils or standard filters for determining the accuracy of mass measurements (i.e., oscillation constant, K_o), and are not included in this procedure.

I.6.2 AUDIT PROCEDURE

The auditor shall adhere to the procedures in Subsections I.6.2.1 and I.6.2.2 below during the audit of the TEOM PM_{10} sampler.

I.6.2.1 EQUIPMENT

Transport the following equipment to the monitoring site for use in the audit:

a. Two certified (NIST traceable) flow transfer standard (FTS) volumetric flow meters (i.e., Chinook Streamline Orifice Transfer Standard). One FTS calibrated in the 0-30 standard liters-per-minute range to measure total flow rates and the other FTS in the 0-5 standard liters-per-minute range to check sample flow rate.

b. A certified digital manometer or 'U-tube' oil or water manometer

c. Fittings: 3/8-inch Swagelok cap, 3/8-inch x 3/8-inch union

d. Tools: Adjustable 6- and 8-inch wrenches, 9/16-inch combination wrench, 3/8-inch combination wrench

e. A watch or clock calibrated to Standard Time

f. Certified transfer standard (NIST traceable) for measuring ambient temperature, with an accuracy of ±.5 °C and a resolution of 0.1 °C

g. Certified barometer (NIST traceable) for measuring ambient barometric pressure with an accuracy of ±5 millimeters of mercury (mmHg) over a range of 550 to 800 mm Hg and a resolution of 1 mm Hg

h. A TEOM Audit Data Worksheet (Figure I-35)

I.6.2.2 FLOW RATE METHOD

Since accurate measurement of particulate mass concentration is dependent upon flow rates under actual conditions, the audit must also be conducted in terms of actual conditions. The audit transfer standard's calibration data are corrected to the United States Environmental Protection Agency's (U.S. EPA) reference conditions (298°K, 760 mm Hg). Therefore, a conversion must be calculated to adjust the SLPM flow rate (Qstd) to an actual LPM flow rate (Qa). The audit FTS calibration relationship is expressed in terms of standard volumetric flow rate (Qstd) as indicated by the audit FTS; these units are in SLPM.

NOTE: During the audit, inspect the overall condition of the monitor (wiring, monitor and inlet cleanliness, etc.) and the monitor's maintenance records.

a. If applicable, ensure TEOM is off-line from the data logger.

b. Reset the Series Monitor (Data Stop) by pressing the <F1> key on the front panel of the control unit.

c. Complete the TEOM Audit Worksheet with the required information, including date, time, flow rates (l/min), ambient temperature (Ta) in degrees Celsius, and ambient barometric pressure (Pa) in mmHg.

d. Insert the audit thermometer probe into the PVC pipe housing of the TEOM temperature probe on the down-tube below the sampler inlet. Allow several minutes for the audit thermometer and TEOM temperature to equilibrate.

e. Scroll the display on the control unit to the main (sample) and auxiliary (bypass) flows. The display represents the actual volumetric flows (Qa) measured by the monitor's flow controllers with temperature and pressure corrections.

f. Confirm that these flows are within ±2% of their set points (3 l/min for the main flow and 13.7 l/min for the auxiliary flow). Any greater deviation may indicate plugged in-line filters or other blockages in the system. If this is the case, all data collected up to this period from the last calibration date may be subject to invalidation.

NOTE: The US EPA has approved of a flow splitter that allows the main flow rate set point to be 3.00, 2.00, or 1.00 l/min. If the TEOM is equipped with an approved flow splitter manufactured by R&P, caution is needed when auditing the device. Be aware that the audit program is not set up to calculate design flow rates other than 3.00 l/min and 13.7 l/min. If the 2.00 l/min flow splitter is installed, the auxiliary flow rate will be 14.7 l/min. If the 1.00 l/min flow splitter is installed, the auxiliary flow will be 15.7 l/min. Total flow rate does not change, so be aware of this when entering the data into the computer.

g. Carefully remove the sampler's inlet by placing one hand on the base of the filter head and the other on the down-tube of the tripod, gently twisting the filter head up and off.

h. Replace the inlet with the FTS using the same gentle twisting motion.

i. Connect the manometer hose to the nipple on the high-flow FTS mass flow meter. Allow the manometer reading to stabilize for at least five minutes.

j. Read the total flow on the manometer and record as Qman on the audit data worksheet. (Convert the manometer reading by making the necessary calculations to obtain the corrected volumetric flow rate for the current ambient temperature and barometric pressure. The volumetric flow measured by the audit flow meter must be 16.7 l/min ±10% to be acceptable.)

k. Disconnect the bypass flow line where it connects to the bypass flow splitter filter and cap the exit of the flow splitter with the 3/8-inch Swagelok cap.

l. Disconnect the FTS hose from the high-flow FTS and connect the line to the output of the low-flow FTS. Allow the manometer to stabilize for at least five minutes.

m. Read the display on the manometer. (Once again convert the manometer reading to a flow. The volumetric flow must equal 3.00, 2.00, or 1.00 l/min ±7% to be acceptable.) Record under the Qman for the main flow on the audit data worksheet.

n. Read the control unit's main flow and record as Qa on the audit data worksheet.

o. Disconnect the flow audit adaptor line from the low-flow FTS and reconnect the line to the output of the high-flow FTS. Allow the flow reading to stabilize for five minutes.

p. Disconnect the 3/8-inch tubing from the flow audit adaptor; connect the tubing to the bypass flow line using the 3/8-inch x 3/8-inch union.

q. Read the display on the audit transfer standard and record as auxiliary flow Qman on the audit data worksheet.

r. Read the auxiliary flow from the control unit. Record this under monitor auxiliary flow Qa on the audit data worksheet.

s. Record the total flow from the control unit by adding the values of the main and auxiliary flow rates. Total flow is reported as total Qa on the audit data worksheet.

t. Remove the cap from the exit of the bypass flow splitter filter and replace the bypass flow line.

REQUIRED: If the TEOM fails the audit, perform a system leak check. Close the valve on the flow audit adaptor. Both the main (sample) flow and auxiliary (bypass) flow should read less than 0.15 l/min on the four line display of the control unit. If one of the flows is greater than 0.15 l/min, then the system is not leak tight. In this case, check hose fittings and other critical locations in the flow system for leaks.

u. Read record, and compare the date, time, temperature, and barometric pressure of the TEOM readings versus the audit readings.

v. Disconnect the audit flow device from the audit transfer standard.

w. Remove the flow adaptor.

x. Replace the inlet on the top of the flow splitter. (The instrument is now back to its normal operating configuration.)

y. Reset the Series TEOM monitor by pressing the <F1> key or "Run" on the front panel of the control unit. (The instrument will automatically begin data collection after the temperature and flow rates have remained stable at their set points for one hour.)

z. Ensure the TEOM is back on line an operating correctly.

I.6.3 AUDIT DATA REPORTING

The operating agency should be given a copy of the audit preliminary results at the completion of the audit. The audit data sheet should be signed by both the auditor and operator, and the results should be discussed. A post-audit verification of audit equipment and data is essential before inferences can be drawn regarding the sampler's performance. The auditor should be able to support audit data with equipment verification documentation.

Final verified audit data shall be submitted to the operating agency as soon as possible. If a sampler exhibits unsatisfactory agreement with the verified audit results, a calibration shall be performed as soon as possible.

I.6.4 AUDIT FREQUENCY

For State and Local Air Monitoring Stations (SLAMS), flow rate audits shall be conducted on at least 25 percent of the operational samplers in the monitoring network each quarter such that each sampler is audited at least once a year. If there are fewer than four TEOM PM_{10} monitors in the network, re-audit one or more randomly so that one is audited each calendar quarter.

Quality Assurance Audit of TEOM PM_{10} Sampler
for Department of Environmental Quality

Auditor _________________ Organization

Site ___________________ Sampler Model ________ S/N

Date __________________ Time

Flow Audit Transfer Standard:
Pressure Audit Transfer Standard:
Temperature Audit Transfer Standard:

Flow Type	TEOM Indicated Q_a, (lpm)	Audit Q_a, (lpm)	Q_a % Difference[1] ±	Design Difference[2] ±
Total (main + auxiliary, nominally 16.7 lpm)				
Actual (main, nominally 3 lpm)				

Sampler's Indicated T_a, °C	Audit T_a, °C	Difference, °C (Sampler - Audit)	Sampler's Indicated P_a, mm Hg	Audit P_a, mm Hg	Difference, mm Hg (Sampler - Audit)

Standard Time

TEOM time on digital display

Time difference

[1]Q_a percent difference = [(Sampler Q_a - Audit Q_a)/Audit Q_a] x 100

[2]Design percent difference = [(Audit Q_a - Design Q_a)/Design Q_a] x 100

Figure I-35.TEOM Audit Data Worksheet

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J APPENDIX J: NEPHELOMETERS

STATE OF IDAHO

DEPARTMENT OF ENVIRONMENTAL QUALITY

AIR MONITORING QUALITY ASSURANCE

STANDARD OPERATING PROCEDURES

FOR

AIR QUALITY MONITORING

RADIANCE RESEARCH MODEL M903 INTEGRATING NEPHELOMETER

MONITORING, MODELING, AND EMISSIONS INVENTORY

MARCH 2003

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Radiance Research Model M903 Integrating Nephelometer

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Acronyms, Units, And Chemical Nomenclature

DC	Direct Current
DEQ	Department of Environmental Quality
lpm	Liters per minute
nm	Nanometer (10^{-9} meter)

Radiance Research Model M903 Integrating Nephelometer

STANDARDS:

State: Not Applicable

Federal: None

METHOD:

An integrating nephelometer estimates the scattering coefficient of light (b_{scat}) caused by aerosols and gases in ambient air. The light scattered from an internally tube-mounted flashing light source is integrated from 5 to 175° deflection and measured by a photodiode detector at the opposite end of the tube.

PRINCIPLE: Integrating nephelometer

RANGE: 0.001 to 1.0 km^{-1} with a time constant of 30 seconds

DETECTION LIMIT: < 0.001 km^{-1} with a time constant of 30 seconds

WAVELENGTH: 475 nm

MANUFACTURER: Radiance Research

J.1 OPERATING PRINCIPLE

An integrating nephelometer measures the scattering coefficient of light (b_{scat}) caused by maintaining a steady ambient airflow rate through an optical tube. The optical tube contains a variable rate flash lamp with a wavelength limiting optical filter of 475 nanometers (nm). At the opposite end of the tube is a photodiode detector that measures light scattered by aerosols and gases in the nephelometer's tube. Light reflected from the inside surfaces of the instrument optical chamber is also measured and integrated into the overall signal strength. The inside reflective component is constant and corrected for by performing zero and span calibrations.

Directly across the optical tube a second photodiode detector measures the output level of light from the lamp. This compensates for any changes in lamp brightness due to power supply changes, lamp aging, and dust on optical surfaces.

The Radiance Research nephelometer is computer based with a menu driven display and toggle switches for control. A serial port is included with the instrument to communicate with an external computer. An internal random access memory (RAM) with battery backup allows for data storage. A nine-pin connector labeled "analog output" can be utilized to collect nephelometer data on a separate datalogger. A constant speed exhaust fan ensures adequate airflow through the system. A purge port is included with the instrument to facilitate calibrations.

J.1.1 SITING CRITERIA

According to the *Interagency Monitoring of Protected Visual Environments (IMPROVE) Visibility Monitoring Guidance Document* (Draft) (Air Resource Specialists, Inc. 1998), nephelometer siting criteria include selecting a location representative of the air mass of interest to the project. Three monitoring definitions (local, regional, and national/global) are used to classify siting for specific monitoring objectives. Because of the localized measuring technique involved with the nephelometer, local measurements are most common. However, a regional approach may be accomplished through the use of multiple monitors.

The unit should not be installed in an area of localized pollution sources (e.g., vehicles, smoke, fugitive emissions, etc.). The site shall be located at least 2.5 times the difference in heights from the nearest obstruction. The nephelometer shall also be installed so that the sample is collected with minimal probe length. The site shall be selected so that vandalism will be minimal, but monthly access not impeded.

J.1.2 INSTALLATION AND SITE DOCUMENTATION

The nephelometer shall be installed in a temperature-controlled environment with a bug/large particle inlet screen. A temperature and relative humidity sensor should be located on a nearby meteorological tower. A datalogger and a calibration system shall also be employed. A 120-volt AC power source shall be made available along with a telephone line and modem for data collection. After installation, the nephelometer shall be calibrated and the system data collection verified. All operators and auditors shall be trained on the operation of the various components. The site shall then be fully documented by completing a site documentation report. The report should include photographic documentation of the following:

- the site,
- electrical wiring,
- local emission sources,
- obstructions, and
- vistas.

The report should also include a site map and geographic coordinates with elevation and the nearby land usage.

J.2 VERIFICATION, SERVICE, AND CALIBRATION

The quality of data collected is a direct result of the level of nephelometer servicing, frequency of site visits, and instrument calibrations.

J.2.1 DAILY MODEM OPERATION CHECKS

Contact the nephelometer daily to check if the instrument is operating within specifications.

J.2.2 ROUTINE SERVICING

J.2.2.1 WEEKLY SITE VISITS

1) Inspect the nephelometer hardware and installation components.
2) Verify that the system has power.
3) Check the system clock(s).
4) Check the condition of the inlet screen and exhaust fan.
5) Perform a zero and span check; recalibrate if necessary.
6) Document any abnormalities with the system.

J.2.2.2 MONTHLY SITE VISITS (EVERY FOURTH WEEK)

1) Assemble monthly zero and span checks for the control charts.

J.2.2.3 ANNUAL SITE VISITS (AS NEEDED)

1) Document the initial condition of the instruments and site.
2) Verify system operation with a zero and span check.

3) Perform a complete calibration of the system.
4) Perform a site inventory
5) Service (clean) or exchange the nephelometer, temperature, and relative humidity sensors (if applicable).
6) Verify serviced or exchanged systems with a complete calibration.

J.2.3 INSTRUMENT VERIFICATION

A method for verifying that the nephelometer is working correctly is executing a Zero/Span check. The instrument should perform acceptably, yielding an adequately precise zero value, and a span value of 95 ±5% of full scale. Additionally, the analog output, or other data communication/recording devices, shall provide the appropriately scaled values for zero and span checks.

J.2.4 CALIBRATION PROCEDURE

The procedures for the zero/span checks and complete calibrations are similar.

1) Apparatus
   a) Clean air pump or cylinder of ultra pure air and a pressure regulator
   b) Filtration system
   c) Canister of span gas (SUVA –134a Refrigerant)
   d) Flow rate measuring device
   e) Tubing (must be compatible with gases utilized)
2) Variables and Terminology
   e) $b_{scat} = \sigma_{sp}$ = bs = extinction coefficient for light scattering

(1) Rayleigh coefficient = light scattering due to particle-free atmospheric gases (altitude dependent)
   f) tc = Data average time constant in seconds
   g) den = average air density (manually set)
   h) zden = air density during zeroing
   i) zero = background suppression as a fraction of calibrator extinction coefficient
   j) gas = theoretical span gas coefficient
   k) span = ratio of internal calibrator to air Rayleigh coefficient
   l) wall = background noise of instrument
   m) local millibars = absolute ambient barometric pressure (mbars x 0.0295 = inches mercury [in Hg]).
   n) local Kelvin = local ambient temperature (^{o}C + 273.16 = K)
3) Procedure
   e) Document the time/date and the day of the week in the appropriate Nephelometer Site Logbook. Upon each site visit, the site operator shall initial the site logbook.
   f) Document the current weather conditions (visibility). Note exceptional visibility events observed during the prior week (e.g., smoke).
   g) Note any abnormalities with any of the following: instrument supports, nephelometer, calibration gas system, or datalogger. Clean the air system (check filter and replace if necessary).
   h) Starting at the first screen (“Radiance Research” displayed), toggle the **Display** - **Next** switch to display the b_{scat} instantaneous value. If applicable, compare this with the value measured by the external datalogger. Next, check the nephelometer and datalogger clocks for accuracy. Note any discrepancies.

i) Toggle to “Temperature and Barometric Pressure” and then manually enter the shelter temperature and barometric pressure values when appropriate (current – for calibrations) by toggling the **Parameter-Raise/Lower** switch.

j) Toggle the **Display – Next** switch until “Cal Gas/Air Set” is displayed. Verify that the appropriate ratio is displayed (SUVA 134a = 7.35).
Note: The cal gas/air ratio is constant for temperature and pressure. The GAS value is computed automatically by the nephelometer when the current temperature and barometric pressure values are input. The calculation is based upon:

$$GAS = \sigma_{sp}(T = 0^o C)\left[\frac{T_{std}}{T_{amb}} \times \frac{p_{amb}}{p_{std}}\right]$$

where,

$$\sigma_{sp}(T = 0^o C)_{SUVA134a} = 14.2 \times 10^{-5} m^{-1}$$

k) Toggle the **Display – Next** switch until the “Zero” screen is displayed.

l) If applicable, disable the datalogger channel for the nephelometer.

m) Turn off the exhaust fan and restrict the outlet with tape.

n) Remove the probe line and connect the clean air source to the inlet of the nephelometer. Introduce 2.0 to 20.0 liters per minute (lpm) of clean air.

o) Switch to fast mode. Wait for approximately five minutes or until a stable reading is obtained. Record the final zero value.

p) Adjust the zero setting if b_{scat} > ±0.05e-5; otherwise, continue with step m. To perform the zero adjustment, wait for a steady value. Once a steady value is obtained, toggle the **Item** switch up (fast response) or down (slower response) while toggling the **Parameter** switch to the proper direction until the b_{sca} value is within the correct range.

q) Depress **Display – Next** once so that the Span screen is displayed.

r) Connect the span gas source to the inlet of the nephelometer. Begin with approximately 2.0 to 20.0 lpm of the span gas.

s) While still in fast mode, wait for approximately five minutes or until a stable reading is obtained. Record the final span value.

t) Using the following equation, compare the b_{scat} to the gas number obtained during the span.

$$\%\ Diff = 100 \times \left(\frac{b_{scat} - Gas}{Gas}\right)$$

u) Adjust the nephelometer span if the percent difference (% Diff) is more than ±10% or is out of control limits.

v) After adjustments to the nephelometer have been completed, perform steps f-p once more, without analyzer adjustment, to ensure proper zero and span settings. Record these values as the final readings. Note: adjustments to the zero can affect the span setting and adjustments to the span can affect the zero constant.

w) Remove the zero/span connector from the inlet. Remove the outlet restrictor. Reconnect all original connections and power up the exhaust fan.

x) If applicable, enable the datalogger channel(s).

J.3 DATA COLLECTION, REDUCTION AND VALIDATION

The Radiance Research nephelometer output data will be measured and collected by a datalogger. The datalogger will record one-hour averages, which will be collected via telephone modem by the Idaho Department of Environmental Quality (DEQ) data acquisition system. The data will then be processed into monthly data reports.

1) The site operator shall review the monthly data reports and flag data associated with calibration, maintenance, and audit activities.
2) The site operator shall flag data associated with rate of changes exceeding 0.05 per kilometer $(km)^{-1}$
3) The site operator shall flag over-range and under-range ($<0.00\ km^{-1}$) data for review.

J.4 DATA REPORTING AND ARCHIVING

J.4.1 DATA REPORTING

1) Data validated monthly by regional offices will be sent to the DEQ State Office for reporting.
2) The DEQ State Office will review and validate the monthly reports upon receipt from the field offices. The flagged data will be identified with the appropriate “null codes” prior to submittal to the Air Quality System (AQS) database.
3) Data will be submitted to AQS database within 90 days of the proceeding quarter.

J.4.2 DATA ARCHIVING

All nephelometer data will be archived in the AQS database.

J.5 PREVENTIVE MAINTENANCE

1) Switch the nephelometer’s power off. Disconnect the inlet tube. Remove the four screws from the dark trap (top section) with an appropriately sized Allen wrench.
2) To remove the dark trap, insert a sharp edge or tap off.
3) Check the condition of the O-ring.
4) File any burrs detected on the flanges of the dark trap or optical tube.
5) Using low pressure compressed gas, blow out any accumulated particles (dust, bugs, spider webs, etc.) from the optical tube and dark trap.
6) Clean the mirror if necessary.
7) Check the aperture ring for debris; clean if necessary.
8) Check for water (stains and/or standing).
9) Check the interior for black paint loss (peeling). If necessary, paint the interior with a flat black paint.
10) Reassemble the unit. Ensure that the baffle is aligned with the lamp.
11) Switch the unit’s power on and observe, through the inlet, that the lamp is flashing. **Warning**: Only look at the lamp for brief periods. The UV light can burn your eye if you stare at the lamp.
12) Clean the inlet tube with compressed air and then reconnect to the nephelometer.
13) If necessary, clean or replace the air filter.

J.6 TROUBLESHOOTING

J.6.1 UNIT NOT OPERATIONAL

1) Check the flash lamp.

2) Check the power cord assembly for broken plugs, frayed insulation, or other signs of damage. A continuity check may be necessary to verify that the power cord is operational.
3) Check the fuse box or the main breaker panel.
4) Check the 12 volt, direct current (DC) transformer for proper output voltages. A digital multimeter will be required to accomplish this task.

J.6.2 NEPHELOMETER DATA ARE CONSISTENTLY HIGH OR LOW

1) If the wall scatter is greater than 75% then water or other material may have contaminated the optical tube and cleaning will be necessary. If cleaning doesn't improve the wall scatter percent, the optical alignment may need to be adjusted.
2) Light may have entered the optical tube. Check the O-ring at the dark trap and the gasket at the lamp.
3) The internal span chopper may be malfunctioning. Check the chopper operation.

J.7 AUDITING THE NEPHELOMETER

A nephelometer performance audit verifies the accuracy of the instrument calibrations. The audit assesses the data for accuracy and ensures the data integrity. Audit the nephelometer at least once per year.

J.7.1 AUDIT PROCEDURE

Follow the general procedure below for the audit.

1) Perform a pre-audit zero and span check with the station calibration system.
2) Perform the audit zero and span check with an independent source of clean air and span gas.
3) Compare the audit calibration results with the station calibration results.
4) Document the results in the log book, or on a field annotated audit form.

J.7.1.1 PRE-AUDIT VERIFICATION

1) Have the site operator perform a weekly zero and span check (Section J.2.2.1) using the station calibration equipment.
2) Record the results in the site logbook and on the Audit Results Worksheet.

J.7.1.2 PERFORMANCE AUDIT

1) Replace the station zero air filter assembly with the independent audit equipment. Replace the station span gas assembly with the independent audit equipment. The equipment should contain the following:

e) Clean air pump or cylinder of ultra pure air and a pressure regulator
f) Filtration system
g) Canister of span gas (SUVA –134a Refrigerant)
h) Flow rate measuring device
i) Tubing (must be compatible with gases utilized)

2) Perform an audit span check following a procedure similar to a monthly zero and span check, utilizing the following steps:
   a) In the nephelometer's first screen ("Radiance Research" displayed), toggle the **Display – Next** switch to display the b_{scat} instantaneous value.
   b) Turn off the exhaust fan and restrict the outlet with tape.
   c) Connect the span gas source to inlet of the nephelometer. Begin with approximately 2.0 to 20.0 lpm of span gas.
   d) Toggle the **Reset – Average** switch. Wait for a stable reading. Record the final value.
   e) Shut off the span gas and connect the clean air source to the inlet.
   f) Run clean air gas at 2.0 to 20.0 lpm. Toggle the **Reset – Average** switch.
   g) Wait for a stable value. Record the final value.
   h) Shut off the clean air gas and remove the zero/span connector from the inlet. Remove the outlet restrictor. Reconnect all original connections and power up the exhaust fan.
3) Record the results on the Audit Results Worksheet and in the site logbook.

J.7.1.3 RESULTS COMPARISON

1) Compare the results of the zero/span check to the results of the performance audit zero/span values and record on the Audit Results Worksheet. This data will be used to determine the total amount of system drift.
2) Use the following equation to calculate the percent differences for the zero/span (station and complete) measurements:

The nephelometer is operating correctly when the percent difference (% Diff) is

$$\%\ Diff = 100 \times \frac{Station(or\ Complete) - Audit}{Audit}$$

   a) less than 15%, and
   b) the zero is ±0.05 E-5 (±5 E-5%).

J.7.1.4 EQUIPMENT

The auditor should now do the following:

1) Ensure the time and date of the datalogger and nephelometer are in agreement to within ±15 minutes.
2) Ensure the nephelometer-displayed readings are within ±5% of the readings recorded on the datalogger.
3) Note any inconsistencies with the siting or physical condition of the site.

J.7.1.5 AUDIT REPORT

The audit report should contain the following components:

1) A general description of the site and pertinent equipment.
2) A description of the audit methodology.
3) The audit zero/span comparisons and the Audit Result Worksheet.
4) Noted inconsistencies.
5) Recommendations for the site.

K APPENDIX K: MULTI-GAS CALIBRATION SYSTEMS

STATE OF IDAHO

DEPARTMENT OF ENVIRONMENTAL QUALITY

AIR MONITORING QUALITY ASSURANCE

STANDARD OPERATING PROCEDURES

FOR

AIR QUALITY MONITORING

THERMO ELECTRON MODEL 146C DYNAMIC GAS CALIBRATOR

AND TELEDYNE API SERIES 700 MASS FLOW MULTI-GAS CALIBRATOR

MONITORING, MODELING, AND EMISSIONS INVENTORY

OCTOBER 2002

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TECO MODEL 146C & API SERIES 700 CALIBRATORS

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TABLES

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TECO Model 146C and API Series 700 Calibrators

Acronyms, Units, And Chemical Nomenclature

API	Advanced Pollution Instrumentation
CPU	Central Processor Unit
DAC	Digital-to-Analog converters
DC	Direct Current
DEQ	Department of Environmental Quality
ESD	electrostatic discharge
FEP	perfluoro (ethylene-propylene) copolymer
IBL	Idaho Bureau of Laboratories
kHz	Kilohertz
LED	Light-Emitting Diodes
MFC	Mass Flow Controllers
nm	Nanometer (10^{-9} meter)
NIST	National Institute of Standards and Technology
NO	Nitrogen Oxide
O_3	Ozone
PCA	Printed Circuit Assembly
PFA	Perfluoroalkoxy
psig	Pounds per Square Inch, Gage
PTFE	Polytetrafluoroethylene
PVDF	Polyvinylidene Fluoride
sccm	Standard Cubic Centimeter per Minute
slpm	Standard Liters per Minute
SOP	Standard Operating Procedure
TECO	Thermo Electron Corporation
UV	Ultraviolet light
VAC	Volts Alternating Current
VDC	Volts Direct Current

REFERENCES

TECO MODEL 146C AND API SERIES 700

MASS FLOW MULTI-GAS CALIBRATORS

This standard operating procedure (SOP) references two different manufacturer's instruction manuals for mass flow multi-gas dilution calibration systems. One of the models is a Thermo Electron Corporation (TECO) Model 146C Multigas Calibration System. This SOP references the February 2000 instruction manual for the TECO Model 146C. The other model is the Advanced Pollution Instrumentation (API) Series 700 Mass Flow Multi-Gas Calibrator. This SOP references the July 1995 instruction manual for the API Series 700. This document combines each of these model's instruction manuals into a general SOP. Where differences exist between the calibrators, the specific model will be referenced and the manufacturer's instruction manual referred to.

K.1 GENERAL INFORMATION

Below are brief introductions into the theory of operation and any necessary operational, and maintenance precautions.

K.1.1 THEORY OF OPERATION

These calibration systems provide precise concentrations of specific gases utilizing any of four possible methodologies. These methodologies are:

1. Precision Gas Dilution,
2. Transfer Standard Ozone Generating Source,
3. Permeation Tube Oven, and
4. Gas Phase Titration.

In each case, a supply of “zero” air is required to dilute the high concentration gases in order to attain the necessary concentrations. Zero air refers to the purity of the diluent gas, indicating a non-detectable concentration of the pollutant under investigation. A zero air source must be available and attached to the appropriate inlet port on the back of the calibrator system. See Figure K-1 for a generic flow and control schematic diagram.

K.1.1.1 Precision gas dilution employs central processor unit (CPU)-controlled precision mass flow controllers (MFC). National Institute of Standards and Technology (NIST) certified gas cylinders, each containing a pollutant gas in an inert (nitrogen) carrier, provide precise gas concentrations through a precision, low flow MFC. Concurrently, relatively high flow rates of diluent zero air are supplied by a second precision MFC. Each MFC provides an electrical signal to the CPU. The CPU calculates the necessary flows to attain the desired pollutant concentration. The equation necessary to calculate the required zero air and pollutant gas flows is:

$$C_f = C_i * \left(\frac{Q_{gas}}{Q_{gas} + Q_{air}} \right)$$

Where: C_f = final concentration of the diluted gas

C_i = source gas concentration

Q_{gas} = volumetric flow rate of the source gas

Q_{air} = volumetric flow rate of the zero air source

The MFC used to control the diluent air has a higher volume capability (approximately 1 standard liter per minute [slpm]) than the MFC used to control the source gas (approximately 10 standard cubic centimeters per minute [sccm], or 0.01 slpm). This allows the control system to develop various gas concentrations, ranging from trace amounts up to high concentrations, limited only by the concentrations available from the NIST traceable gas source. The low flow gas and the high flow diluent are mixed in an inert (Teflon®) chamber prior entering the exhaust manifold where the analyzers to be calibrated pull their samples from.

K.1.1.2 Both of the calibrators can generate ozone (O_3). The equipment contain both an internal O_3 generator and an O_3 photometer. Ozone is generated by exposing the zero air to 185 nanometer light. Light at this wavelength is in the ultraviolet (UV) region of the electromagnetic spectrum. The O_3 concentration is regulated by varying the UV lamp intensity inside the O_3 generator utilizing a feedback loop from the photometer. Diluting the output from the O_3 generator with zero air can provide additional flexibility for varying the concentrations of calibration O_3.

K.1.1.3 A permeation oven can also be installed in these calibration systems. A permeation device is designed to deliver precise concentrations of the contained gas when the permeation tube is maintained at a constant temperature. Zero air is used to entrain the effused gas and deliver a precision concentration of calibration gas. This gas stream can be diluted further to obtain the desired concentrations. Permeation ovens are most effective in supplying gases that can be liquefied at atmospheric temperature and pressure, such as sulfur dioxide and nitrogen dioxide.

K.1.1.4 Gas phase titration can be accomplished when an O_3 generator is present in the calibrator's configuration, coupled with a precise source of nitrogen oxide (NO). Usually, the source of a precise concentration of NO is a NIST traceable, certified gas cylinder. Gas phase titration is performed by mixing a regulated amount of NO with O_3, allowing the species to react in a supplied reaction chamber for a prescribed length of time. The reaction that occurs is:

$$NO + O_3 \Rightarrow NO_2 + O_2 + h\upsilon$$

The output from the reaction chamber is evaluated by a nitrogen oxide analyzer. The difference between the NIST traceable NO concentration and the nitrogen oxide analyzer's reported NO concentration is taken to be the concentration of nitrogen dioxide supplied for analysis.

K.1.2 CAUTIONS

1. Light from the O_3 generator's ultraviolet lamp can burn the eyes. Use protective glasses to view the lamp or look at it only for a few seconds at distances of two or more feet. Do not touch the lamp face.

2. The calibrator contains a high voltage direct current (VDC) power supply for the UV lamp, a 24 VDC switching power supply to operate direct current (DC) operated valves, and 115 volt alternating current (VAC) at the input terminals. When working on this equipment use all high voltage precautions.

3. The calibrator contains both high voltage power supplies and delicate electronics. Use a third wire ground on this equipment to properly ground conducted and emitted transmissions.

4. Electrostatic discharge (ESD) can damage sensitive electronic printed circuits. To limit damage due to ESD, properly ground all work surfaces, and technicians prior to working on this equipment.

5. Improper handling can damage printed circuit boards. Do not touch components on the surface of the boards, or touch the connector leads, or contact surfaces. Oils from human contact will corrode the contacts. Handle by the edges alone.

6. Buildup of excessive concentrations of gas in the permeation tube oven can yield inaccurate concentrations. To prevent this, keep a constant supply of zero air flowing through the permeation tube.

7. Improperly restrained pumps, permeation tube ovens, analyzer benches, and other internal equipment will impair the correct operation of the calibrator. Remove all bench securing screws and tie-down straps prior to applying power.

8. Calibrators can be damaged by too much pressure. Reduce the inlet pressure below 8 pounds per square inch, gauge (psig) prior to capping the outlet during leak and pressure checks.

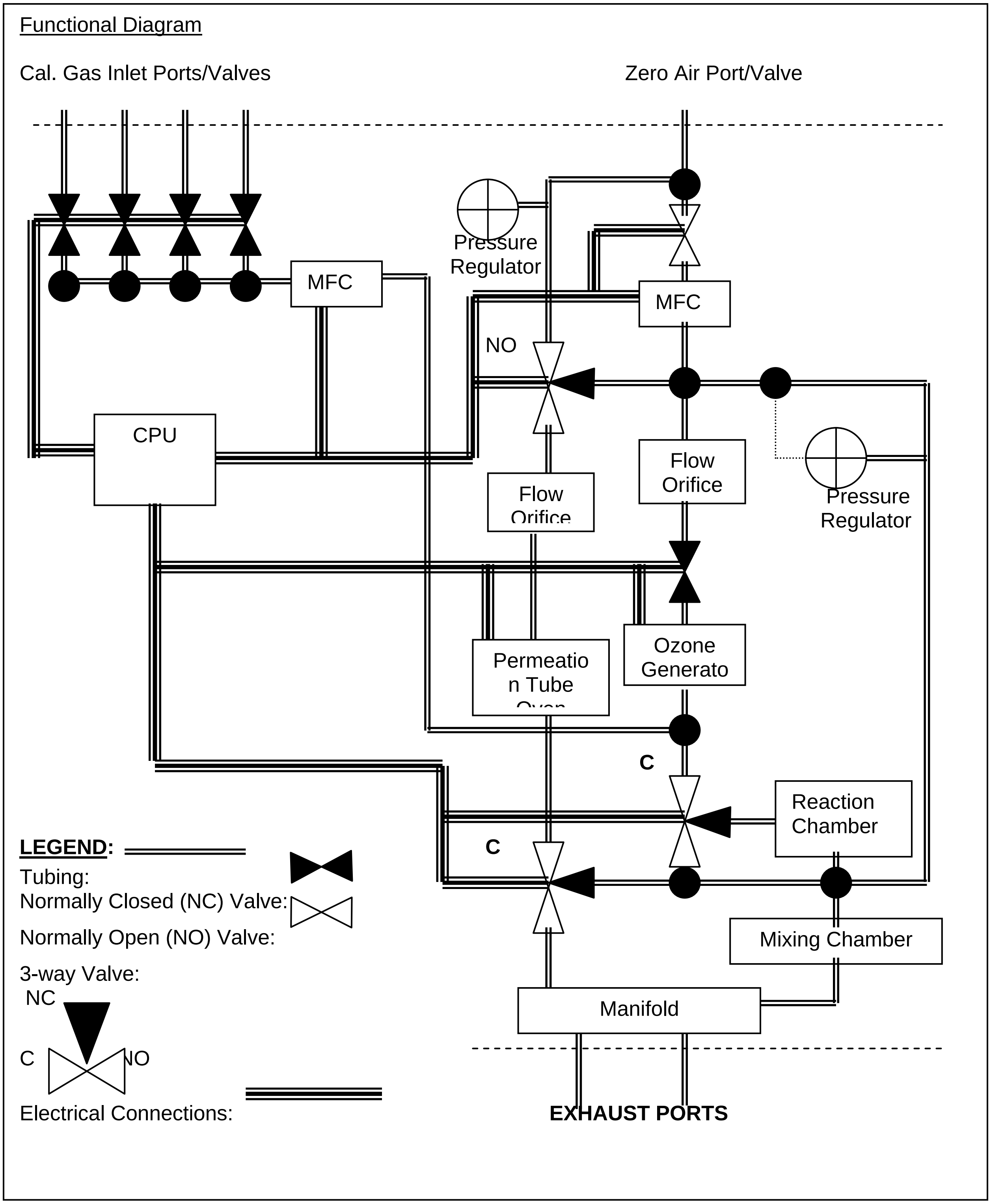

Figure K-1. Generic flow and control schematic.

K.2 ROUTINE SERVICE CHECKS

Verify the functionality of the calibrator periodically according to the calibrator service schedule provide in Table K-1. Utilize the Quality Control Maintenance Check Sheet provided in Figure K-2 to track the months in which the service activity was performed.

Table K-1.TECO Model 146C and API Series 700 Calibrator Service Schedule

ACTIVITY	Quarterly	Semi-Annually	Annually
GENERAL BENCH INSPECTION AND REPAIR OPERATIONS			
Inspect Bench Tubing for Contamination and Damage	X		
Leak Check Bench	X		
Verify Solenoid Valve Function	X		
Replace Inlet Particulate Filter		X	
Inspect Cooling Fan			X
Clean or Replace Cooling Fan’s Filter			X
Inspect/Replace O-Rings			X
Clean Flow Restricting Devices			X
Inspect/Adjust Pressure Regulator			X
Calibrate Bench			X
Replace Sample Pump	As Required		
Replace Inlet and Outlet Fittings	As Required		
OZONE GENERATOR/TRANSFER STANDARD			
Verify Lamp Intensity		X	
Inspect/Replace O_3 Generator Heater	As Required		
Inspect/Replace UV Lam	As Required		
Verify proper O_3 Generator Power Supply output range	As Required		
PERMEATION TUBE			
Verify Permeation Tube Contents		X	
Inspect Permeation Oven			X
MASS FLOW CONTROLLERS			
Verify MFC Output			X
ELECTRONICS/INTERCONNECT/POWER SUPPLIES			
Verify Wire Integrity/Strain Relief Function			X
Inspect Connector Pins/Bodies for bent pins or cracked cases	As Required		
Verify Connectors are Fully Inserted	As Required		
Verify PCAs are Fully Inserted	As Required		
Verify Ozone Transfer Standard Power Supply per Specifications			X

K.3 QUALITY CONTROL MAINTENANCE CHECK SHEET

TECO MODEL 146 & API SERIES 700 CALIBRATION SYSTEMS

Technician:__________________________________Calibrator Property Number:______________________Year:_____________________

ACTIVITY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	SCHEDULE
Inspect Bench Tubing													Quarterly
Leak Check Bench													Quarterly
System Vacuum Check													Quarterly
System Flow Check													Quarterly
Verify Solenoid Valve Function													Quarterly
Replace Inlet Particulate Filter													Semi-Ann
Inspect Solenoid Valve Seats													Semi-Ann
Inspect Tubing for Dirt													Semi-Ann
Inspect Cooling Fan													Annually
Replace Cooling Fan's Filter													Annually
Inspect O-Rings													Annually
Clean Orifices													Annually
Inspect Pressure Regulators													Annually
Calibrate Bench													Annually
Replace Sample Pump													As Req'd
Replace Inlet & Outlet Fittings													As Req'd
Verify Ozone Lamp Intensity													Quarterly
Replace Ozone UV Lamp													As Req'd
Verify Permeation Tube Contents													Quarterly
Inspect Permeation Tube Heater(s)													Semi-Ann
Verify MFC Output against BIOS													Annually
Verify Wire Integrity/Strain Relief													Annually
Inspect Connector Pins / Bodies													As Req'd
Verify Connectors Fully Inserted													As Req'd
Verify PCAs are Fully Inserted													As Req'd
Verify O_3 Power Supply per Spec.													Annually

Figure K-2.Quality Control Maintenance Check Sheet

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NOTE: Cautions listed in Section K.1.2 should be noted while performing troubleshooting or maintenance on the analyzer. Additionally, troubleshooting or repairs must not be performed on any electronics without properly worn and grounded ESD grounding straps.

K.3.1 TUBING

Inspect tubing periodically in accordance with the schedule provided in Table K-1. Damage may consist of, but is not limited to, constrictions, kinks, cuts, nicks, collapsed sections, or visible signs of contamination lining the interior surfaces. Visible signs of contamination may include, but not be limited to, clouding, discoloration, and pitting of the tubing inner surface, cracking, hardening, or any signs of brittleness of the tube, and any change in diameter. Replace all sections that are damaged.

K.3.2 LEAK CHECKS

Perform leak checks per the calibrator's instruction manual. For the TECO Model 146C, perform leak checks as directed in "Leak Checking" on page 7-4 of the manual. For the API Series 700, perform leak checks as directed in "Leak Check Procedure" in the instruction manual.

K.3.3 SOLENOID VALVES

Energize each solenoid valve to verify that it works properly. Any indication that the solenoid valve does not open, or does not close completely, must be investigated further. A rotameter, or other flow-measuring device, can be used to verify that the valve opens and closes completely. Any flow measurable after the solenoid valve is de-energized, for normally closed valves, or energized, for normally open valves, indicates that the solenoid valve must be replaced. Refer to the calibrator's instruction manual for removal and repair procedures.

K.3.4 INLET PARTICULATE FILTERS

Inspect and replace any particulate filters that are dirty. Follow the procedures identified in the calibrator's instruction manual.

K.3.5 COOLING FAN AND FILTER

Inspect the cooling fan to insure that it rotates freely. Remove the filter and clean the fan blades if they appear dirty. Clean the filter with soap and water if it is a resilient material; otherwise, replace the filter. Clean fan filters are necessary to ensure sufficient cooling airflow through the calibrator. Follow the procedures identified in the calibrator's instruction manual.

K.3.6 O-RINGS

Inspect and replace any O-ring seals that exhibit surface cracking, discoloration, brittleness, or any other characteristic that indicates the material has degraded due to chemical exposure.

K.3.7 FLOW RESTRICTING DEVICES

Inspect, clean, and/or replace any flow restriction devices. Flow restricting devices usually consist of critical orifices or capillary tubes. Other restricting configurations are possible. Verify that the device is clean and operating properly. Follow the procedures identified in the calibrator's instruction manual for disassembly, inspection, cleaning, and replacement.

K.3.8 PRESSURE REGULATOR INSPECTION/ADJUSTMENT

Inspect the pressure regulators for proper operation. Any indication that the pressure regulators are not operating properly must be addressed immediately. Adjust the pressure regulator as indicated in the calibrator's instruction manual. TECO Model 146C instructions are located on page 7-5.

K.3.9 CALIBRATION BENCH

Calibrate the calibration system according to the schedule provided in Table K-1. Follow the instructions in the calibrator's instruction manual.

K.3.10 SAMPLE PUMP

On those systems provided with sample pumps, inspection, repair, and possibly replacement are needed periodically. Be aware of the pump's operation while performing leak checks and flow inspections. Any indication of substandard pressures, vacuums, or flows may indicate that the pump needs to be refurbished or replaced. Refer to the calibrator's instruction manual for proper removal, repair, and replacement procedures.

K.3.11 FITTINGS

Repeated use of fittings can damage the threads and forcing cones. Any chips, dents, cracks or other non-standard configuration to the fitting indicates that the fitting has been damaged and must be replaced to ensure a proper seal is provided. Replace fittings with acceptable materials only. Acceptable materials include, but may not be limited to, stainless steel, Teflon® (PTFE or FEP), or Kynar® (polyvinylidene fluoride [PVDF]).

K.3.12 OZONE GENERATOR HEATER

Periodically inspect the operation of the ozone generator heater. Replace, following the instructions in the calibrator's instruction manual, if an insufficient or fluctuating module temperature is observed.

K.3.13 ULTRAVIOLET LAMP

Periodically inspect the operation of the ozone generator. Replace, following the instructions in the calibrator's instruction manual, if insufficient or fluctuating O_3 concentrations are observed.

K.3.14 OZONE GENERATOR POWER SUPPLY

Periodically inspect the operation of the O_3 generator. Replace, following the instructions in the calibrator's instruction manual, if insufficient or fluctuating O_3 concentrations are observed.

K.3.15 PERMEATION TUBE

Inspect the operation of the permeation tube semi-annually. Replace the permeation tube, following the instructions in the calibrator's instruction manual, if insufficient or fluctuating concentrations are observed.

K.3.16 PERMEATION OVEN

Annually inspect the operation of the permeation oven. Replace the permeation tube heater, following the instructions in the calibrator's instruction manual, if insufficient or fluctuating concentrations are observed.

K.3.17 MASS FLOW CONTROLLERS

Annually inspect the operation of the MFCs. Replace, repair, or calibrate the MFCs, following the instructions in the calibrator's instruction manual or the Idaho Bureau of Laboratories' (IBL) MFC calibration procedure, if inaccurate or fluctuating flow rates are observed.

K.3.18 INTERCONNECT (WIRING HARNESS)

NOTE: Prior to touching any electrical/electronic components, verify that the power is shut off, power cord disconnected, work surface properly grounded, and that the technician is wearing a properly grounded wrist strap to limit potential ESD damage.

Inspect the electrical interconnect (wiring harness) for damage due to chemicals or physical abuse annually. Physical abuse includes being exposed to excessive heat, cutting the insulation, smashing or crimping the wires when the covers are closed, or installing equipment . Damage may exhibit itself as discolored, missing, or smashed/displaced insulation.

Additionally, connectors may be disconnected, or damaged inadvertently during maintenance, repair, and calibration operations. Carefully inspect the connectors for damage to their bodies, such as cracked and chipped surfaces. Verify that all connectors are securely seated into their mating connector. While the connector is disconnected, visually inspect the face for missing and/or bent pins. Finally, annually verify that the strain relief securely retains the wire bundle where it enters the connector. Any damage identified should be assessed, and if deemed necessary, repaired immediately. Consult the operations manual for proper repair procedures.

K.3.19 ELECTRONICS

NOTE: Prior to touching any electrical/electronic components, verify that the power is shut off, power cord disconnected, work surface properly grounded, and that the technician has a properly grounded wrist strap on to limit potential ESD damage.

Individual printed circuit assemblies (PCA) must be periodically detached and inspected. The PCAs to inspect include, but may not be limited to:

- Processor PCA
- Analog to Digital PCA
- Digital to Analog PCA
- Input/Output PCA
- DC Power Supply PCA
- Ozonator PCA
- Permeation Oven Temperature Control PCA
- Mother (Back Plane) PCA

The electronics attached to the PCAs must be inspected for discolored components, darkened areas, and disconnected components. Each of these signs indicates a major electrical discharge incident, and the effected PCA(s) must be replaced. Additionally, the entire instrument must be thoroughly inspected for any collateral damage to the interconnect (wiring harness), sensors, displays, keypads, and other electrical components. Follow the calibrator's instruction manual for repair and replacement procedures.

Dust off the PCA and reinsert into the mating connector. Removing the dust will help the electronics operate at a lower temperature and will reduce the likelihood of arcing damage to adjacent components. Be careful not to damage components or the connector pins during cleaning and reinsertion.

K.3.20 POWER SUPPLIES

NOTE: Prior to touching any electrical/electronic components, verify that the power is shut off, power cord disconnected, work surface properly grounded, and that the technician has a properly grounded wrist strap on to limit potential ESD damage.

Clean any accumulated dust, lint, and other foreign matter from the surface of the power supplies and any associated PCAs. Inspect for any apparent ESD damage. Replace the power supply if the outputs do not meet the specifications provided in the calibrator's instruction manual. Reinstall as indicated in the calibrator's instruction manual.

Table K-2 provides descriptions for the modules located in the various power supplies.

Table K-2. Power Supply Module Subassemblies

MODULE	DESCRIPTION
Linear Power Supply PCA[a]	The linear power supply PCA takes multiple voltage inputs from the power transformer and produces +5, +12, ±15, and 24 VDC[b] outputs. The outputs are routed to two external connectors. The +5 VDC is used for operating the CPU. The ±15 VDC is used in several locations for running op-amps and ICs. The +12 VDC is used for operating the fans and valves.
Switching Power Supply	The switching power supply provides +24 VDC at 4 amps to the UV[c] lamp power supply module. There is a load resistor on the switch PCA to keep the output stable when little current is required from the supply.
Switch PCA	The switch PCA has many different functions. It takes logic signals from the V/F[d] PCA and uses them to switch 4-115 VAC[e] and 4-12 VDC loads. The PCA also contains the instrument central grounding tie point. It routes un-switched AC and DC power as needed. This PCA provides access to program the power transformers to accept 115, 220, or 240 VAC inputs.
Power Transformers	There are potentially two input power transformers in the instrument. The multi-tap transformer is in every API Series 700 and supplies input power for the linear power supply PCA. A second transformer is added if 220 or 240 VAC input is required. Input power selection is done via a programming connector that provides the proper connections for either foreign or domestic power.
Circuit Breaker/Power Switch	The front panel contains a combination circuit breaker/input power switch, which is connected to the power supply module. If an overload is detected the switch goes to the OFF position. Switching the power back on resets the breaker.

[a] Printed Circuit Assembly
[b] Volts, Direct Current
[c] Ultraviolet
[d] Voltage/Frequency
[e] Volts, Alternating Current

K.4 TROUBLESHOOTING

K.4.1 GENERAL INFORMATION

NOTE: Cautions listed in Section K.1.2 should be observed while performing troubleshooting or maintenance on the analyzer. Additionally, troubleshooting or repairs must not be performed on any electronics without properly worn and grounded ESD grounding straps.

As with all electrical/electronic equipment, the DC power supplies are the first items that should be checked when a problem occurs. The following instructions assume that the DC power supplies have been checked and eliminated as the potential problem.

If status light emitting diodes (LEDs) are present, a lit or flashing red LED may indicate a warning condition exists and requires attention. See the calibrator's instruction manual for use of LEDs, warning lights, or other forms of warning notification.

K.4.2 TROUBLESHOOTING GUIDE

Periodically, calibrator operation will be problematic. In such situations, refer to Table K-3 for guidance in identifying and rectifying the situation.

Table K-3. Troubleshooting Guide.

MALFUNCTION	POSSIBLE CAUSE	ACTION
Flow Controller Unstable	1. Gas or zero air source not adequate or pressure too low. 2. Flow controller malfunction. 3. Leak.	1. Increase pressure (to greater than 25 psig), and/or flow from gas, and/or zero air source. 2. Refer to flow controller manual in calibrator's instruction manual. 3. Execute a leak check as indicated in the calibrator's instruction manual.
Solenoid not switching in local mode	1. Instrument in remote mode. 2. Solenoid malfunction. 3. Solenoid driver malfunction.	1. Put instrument in local mode 2. Check solenoid for continuity and replace as necessary. 3. Check power supply.
Solenoid not switching in remote mode.	1. Instrument in local mode. 2. Input/output PCA failure. 3. Bad connectors.	1. Put instrument in remote mode. 2. Replace appropriate PCA. 3. Replace connectors.
Calibration as measured at output of MFC does not agree with calibration as measured at output of instrument.	1. Leak.	1. Perform leak check.
No O_3 output.	1. Lamp failure. 2. Ozonator heater failure.	1. Check for blue light when removing O_3 lamp from ozonator and replace lamp if light is not visible. 2. Check to see that ozonator is warm (≈50 °C). If not, replace or repair heater

MALFUNCTION	POSSIBLE CAUSE	ACTION
	3. Ozonator power supply failure.	or heat power supply. 3. Repair or replace ozonator power supply.
Low O_3 output.	1. Leak in ozonator or distribution manifold. 2. Flow excessively high. 3. Power supply failure. 4. Weak lamp.	1. Check for leaks in ozonator or manifold system and repair leak. 2. Check zero airflow valve and adjust to less than 8 slpm. 3.Voltage on primary of step-up transformer with ozonator level set to 100% should be greater than 16 volts. If not, repair or replace ozonator power supply. 4. Check to see that there is a bright blue light when removing the ozone lamp. If not, replace lamp.
Unstable O_3 output.	1. Failure of analyzer measuring O_3. 2. Leak in system. 3. Zero airflow unstable. 4. Lamp failure. 5. Defective O_3 power supply.	1. Repair analyzer. 2. Check for leaks and repair. 3. Check zero airflow meter. 4. Replace with new lamp. 5. Verify lamp power supply is providing a 15 kHz square wave. If not, repair or replace power supply.
Permeation oven fails to warm up.	1. Not enough time has elapsed since turning oven on. 2. Oven heater circuit is shorted or open. 3. Heater voltage not present or improperly calibrated. 4. Control circuit malfunction. 5. Set point not set properly.	1. Wait one hour from powering up instrument. 2. Replace oven. 3. Follow adjustment procedures outlined in calibrator’s instruction manual. 4. Replace permeation oven PCA. 5. Check for correct resistors. Refer to calibrator’s instruction manual for the correct resistor to set the oven temperatures.
Temperature display erratic.	1. Flow through permeation tube oven is not constant.	1. Clean flow restricting device and critical orifice or capillary; readjust regulator as indicated in the calibrator’s instruction manual.

Table K-4. Series 700 Front Panel Warning Messages

MESSAGE	DESCRIPTION
SYSTEM RESET	System was powered on or reset. This warming occurs every time the instrument is powered up, as in after a power failure. It can also occur if the RAM[a] or EEPROM[b] is reset.
RAM INITIALIZED	RAM was erased and re-initialized. The RAM contains temporary data used by the Series 700. No setup variables are stored in the RAM.
CAL[c] GAS PRESSURE WARNING	Calibration gas pressure is above 30 psig[d] or below 25 psig. If the gas pressure is above 33 psig or below 15 psig, the CPU will shut off the valve system for safety.
DILUENT PRESSURE WARNING	Diluent air pressure above 30 psig or below 25 psig. If the gas pressure is above 33 psig or below 15 psig, the CPU will shut off the valve system for safety.
REGULATOR PRESSURE WARNING	Regulator pressure is below 15 psig or above 25 psig.
CAL GAS/DILUENT FLOW WARNING	Calibration gas or diluent air rate through each corresponding mass flow controller is less than 10% of full scale.
V/F[e] CARD NOT INSTALLED	V/F card was not detected on power up. This probably means either: 1. the PCA[f] is not seated in the mating connector or 2. the PCA is defective.
PHOTOMETER LAMP TEMPERATURE WARNING (option)	Photometer lamp temperature is below 51 °C or above 61 °C.
O_3 GENERATOR LAMP TEMPERATURE WARNING (option)	O_3 generator temperature is below 43 °C or above 53 °C.
PHOTO REFERENCE WARNING (option)	Photometer reference reading is below 2,500 mV[g].
O_3 GENERATOR REFERENCE WARNING (option)	O_3 generator reference reading is below 50 mV. This warning is set only during reference feedback mode.
PERM[h] TUBE TEMPERATURE WARNING (option)	The permeation tube temperature is below 49 °C or above 51 °C.

a Random Access Memory
b Electronically Erasable / Programmable Read Only Memory
c Calibration
d pounds per square inch gauge
e Voltage/Frequency
f Printed Circuit Assembly
g millivolts
h permeation

Figure K-3. API Series 700 Diagnostic Modes Summary

MESSAGE	DESCRIPTION
SIGNAL I/O[a]	Gives access to the digital and analog inputs and outputs on the V/F[b] PCA[c]. The status or value of all of the signals can be seen. Some of the signals can be controlled from the keyboard. NOTE – some signals can be toggled into states that indicate warnings or other faults. These settings will remain in effect until the DIAG[d] mode is exited. The Series 700 will then resume control over the signals.
ANALOG OUTPUT	Causes a test signal to be written to the analog output DAC[e] converters. The signal consists of a scrolling 0%, 20%, 40%, 60%, 80%, and 100% of the analog output value. The scrolling may be stopped by pressing the key underneath the "%" display to hold that value.
DAC CALIBRATION	The analog output is created by four DAC. Two (DAC 0 and DAC 1) are dedicated for MFC[f]. DAC 2 is for the O_3 generator control output, and DAC 3 is for the test channel output. This selection starts a procedure to calibrate these outputs. Refer to Section 9.1.4.1 of the API[g] Series 700 instruction manual for a detailed procedure.
TEST CHANNEL OUTPUT	Recorder output on the rear panel is used for the test channel output. See Section 9.1.3.1 and Figure 2.2 of the API Series 700 instruction manual for a detailed procedure.
AUTO LEAK CHECK	This diagnostic feature is part of an option with supporting hardware. It performs the automatic leak check. Refer to Section 8.2 of the API Series 700 instruction manual for a detailed procedure.
RS-232 OUTPUT	Causes a one-second burst of data to be transmitted from the RS-232 port. Used to diagnose RS-232 port problems. See Section 9.2.4 of the API Series 700 instruction manual for RS-232 port diagnostic techniques.

[a] Input / Output
[b] Voltage / Frequency
[c] Printed Circuit Assembly
[d] Diagnostic
[e] digital-to-analog
[f] Mass Flow Controller
[g] Advanced Pollution Instrumentation

K.5 ACCEPTANCE PROCEDURES

K.5.1 GENERAL INFORMATION

Before beginning acceptance testing of the calibrator, read the manual thoroughly. Then, initiate an instrument logbook and an Acceptance Test Mini-Report (Figure K-3).

K.5.2 PHYSICAL INSPECTIONS

Unpack the calibrator and check for physical damage. Remove the top cover from the calibrator and perform the following tasks:

NOTE: Prior to touching any electronics, properly ground yourself to the calibrator's housing to prevent ESD damage to the circuit cards.

1. Access the electronics; extract and reinsert the printed circuit boards.

2. Check for correct power cord phasing; standard wiring configuration has the black wire connected to the brass terminal of the plug, white to copper, and green to earth ground. Verify the analyzer chassis is grounded to earth ground.

3. Verify that the calibrator is complete upon receipt. (i.e., manuals, selected options, rack mount slides, etc. all present).

K.5.3 OPERATIONAL TESTS

Perform the following operational checks and record the results on the strip chart and mini report. Refer to the calibrator's instruction manual for specific directions to perform the following operational exercises.

1. Actuate all valves to verify functionality.

2. Test the pressure regulators for stable response over the input pressure range.

3. Verify that all meters (flow, pressure, temperature, etc.) accurately report the characteristic.

4. Verify that any pumps function within specification.

5. Actuate all switches, electromechanical and electronic, to verify that they are functioning properly.

6. Verify that MFCs are functioning properly:

    a. Verify that the low flow MFC module reports flows within tolerance of the calibration report.

    b. Verify that the high flow MFC module reports flows within tolerance of the calibration report.

7. Verify that the permeation tube oven heats the permeation tube to the specified temperature, within the reported tolerance range.

8. Verify that the UV lamp emits an intense blue light.

9. Verify that the O_3 generator heater heats the ozonator to the specified temperature, within the reported tolerance range.

10. Verify that the thermistors generate the appropriate resistance change for an applicable temperature range.

11. Verify that all indicator lamps are functional.

12. Verify that the O_3 generator provides an appropriate O_3 concentration.

13. Verify that the Permeation Tube provides the appropriate concentration.

14. Characterize the MFC:

    a. Characterize the low flow MFC according to the IBL characterization procedure.

    b. Characterize the high flow MFC according to the IBL characterization procedure.

TECO MODEL 146C & API SERIES 700 CALIBRATORS
ACCEPTANCE TEST "MINI REPORT"

Date of Review:________________
Reviewed By:____________________
Serial No.______________________
Date of Acceptance_____________

I. Physical Inspection — Passed / Failed / Final OK

	Passed	Failed	Final OK
E. Checked for shipping damage	_____	_____	________
F. Checked all electrical wiring	_____	_____	________
G. Checked all Plumbing for leaks	_____	_____	________
H. Analyzer complete upon receipt	_____	_____	________

V. Operational Tests — Passed / Failed / Final OK

a) Checked operation of:

	Passed	Failed	Final OK
i) Valves		_____	_____
________			
ii) Pressure Regulators	_____	_____	________
iii) Meters		_____	_____
________			
iv) Pumps	_____	_____	________
v) Switches	_____	_____	________
vi) Mass Flow Controller (Low flow)	_____	_____	________
vii) Mass Flow Controller (High flow)	_____	_____	________
viii) Perm. Tube Oven	_____	_____	________
ix) UV Lamp	_____	_____	________
x) O_3 Generator Heater	_____	_____	________
xi) Thermistors	_____	_____	________
xii) Pressure Sensors	_____	_____	________
xiii) Indicator(s) lamp(s)	_____	_____	________

VI. Tests Performed (Attach Charts) — %FS Dev. / Range / Pass / Fail / Final OK

I. Verify O_3 Generator Concentration ________ ______ ____ ____
____
J. Verify Permeation Tube Concentration ________ ______ ____ ____ ________
K. Characterize Low Flow MFC Range ________ ______ ____ ____
____
L. Characterize High Flow MFC Range ________ ______ ____ ____ ________

VII. Special Tests: ____
____
____
____

V. Comments/Maintenance Performed: _________________________________
____
____
____

Figure K-4.Acceptance Test Mini-Report

K.6 CHARACTERIZATION PROCEDURE

K.6.1 INTRODUCTION

The Department of Environmental Quality (DEQ) annually extracts the MFCs from the calibrators and sends them to be recertified. Recertification requires that the MFCs' output be compared to a primary flow standard for precision, bias, accuracy, and repeatability.

Additionally, DEQ characterizes each MFC upon its return. Characterization is done in order to increase the accuracy of the multi-gas calibration system. Characterization requires that the MFCs' output is recorded and compared to the output of a primary flow standard. No adjustments are made to the MFC. A minimum of five points are tested. The values are recorded and tabulated for future use. The characterization sequence may be performed multiple times to verify repeatability.

K.6.2 APPARATUS

The following equipment and resources are required to characterize an MFC:

1. Gas cylinder - zero Air, free of contaminants (particulates, gases, etc.)
2. Primary flow standard
3. MFC
4. 30 psig pressure regulator
5. Control valve (needle)
6. One-quarter or one-eighth inch FEP or PFA Teflon® tubing for airflow connections
7. Necessary fittings: acceptable fitting materials include 316 stainless steel, FEP Teflon®, or Kynar® (PVDF)

Assemble the equipment as shown in Figure K-1.

K.6.3 CHARACTERIZATION PROCESS

Characterizing the MFCs is critical in order to assure the accuracy of the diluted gas concentrations. The accuracy of mass flow controlled dilution is susceptible to atmospheric pressure variations. The controllers may not deliver the same mass flow in differing ambient environments. Consequently,

1. Set up the equipment according to the diagram provided in Figure K-1.
2. Select a minimum of five set points that will be used to characterize the MFC. If the MFC is a low flow unit (0 – 30 sccm), select the points, equally spaced between 10% full scale and 90% full scale (e.g., 10%, 30%, 50%, 70%, and 90% full scale). Select similar set points for the high flow MFC (0 – 10 slpm) (1.0 slpm = 1000 sccm).
3. Exercise the MFC according to the set points. Record the MFC response to each flow rate in the MFC Characterization Datasheet provided in Figure K-6.

4. Generate a graph that relates the true flow rate to the MFC reported flow rate by plotting the known mass flow against the MFC reported flow rate on the same graph.

    a. Plot the known mass flow on the abscissa (x-axis), and

    b. Plot the MFC's reported flow on the ordinate (y-axis).

5. Reinstall the MFC into the calibrator.

6. Insert a copy of the characterization curve in the calibrator's documentation/instruction manual and retain the original data set in the files.

NOTE: A perfectly calibrated MFC will yield a straight line issuing at a 45° angle from the origin of the graph. Any deviation from this 45° angle indicates that the MFC is not providing an accurate supply of gases. If the line makes an angle greater than 45° from the x-axis, the MFC is providing more gas than the calibration standard. Similarly, if the angle is less than 45° from the x-axis, the MFC is providing less gas than the calibration standard. Sever deviations from 45° indicate that the MFC should be replaced.

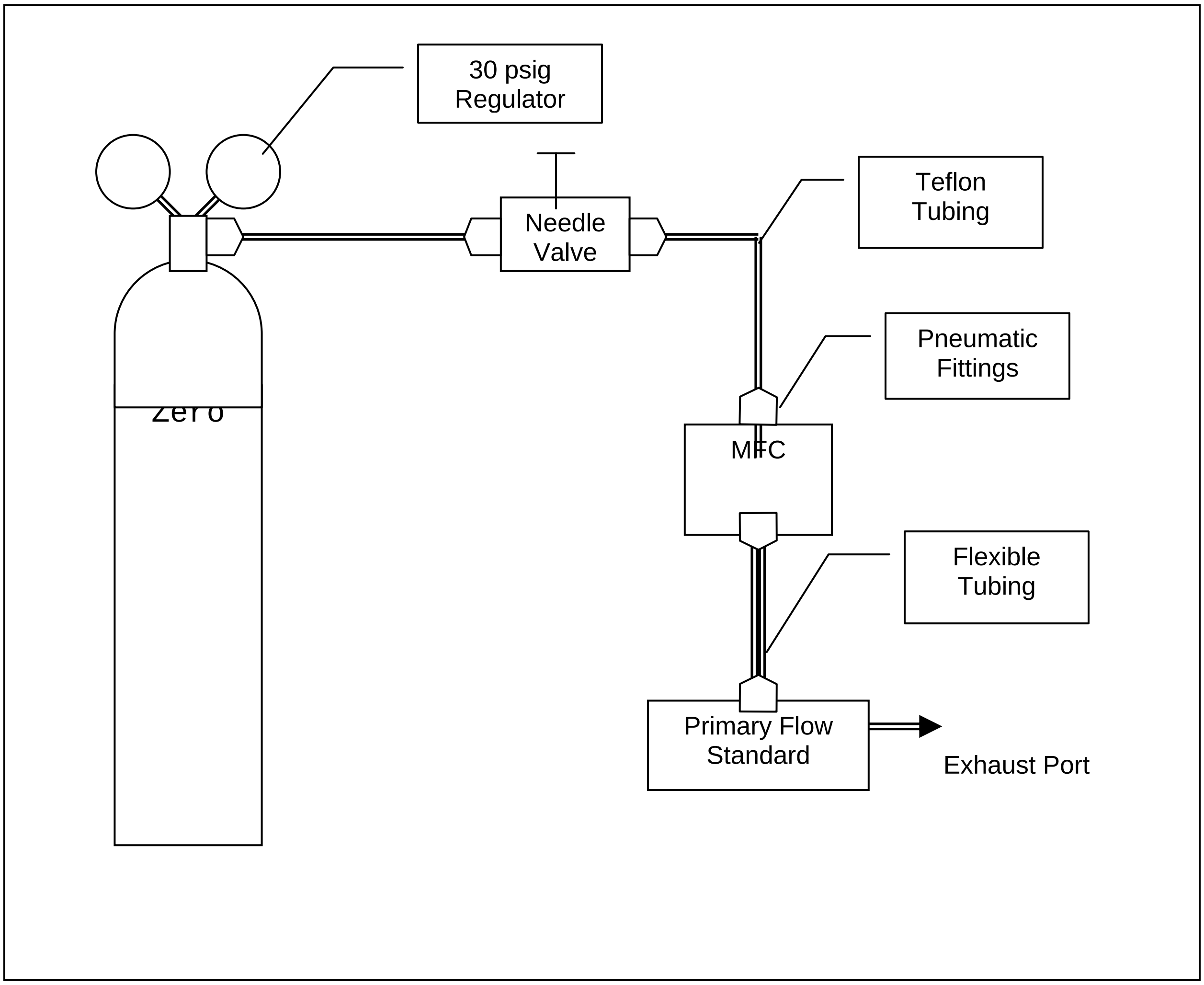

Figure K-5. Mass Flow Controllers Characterization Apparatus Diagram

IDAHO DEPARTMENT OF ENVIRONMENTAL QUALITY
MFC CHARACTERIZATION DATASHEET

INSTRUMENT:
Make & Model:__________________ Property No:__________________________
Serial No:______________________ MFC SERNO: ___________________
______
Date:__________________________ MFC Range:__________________________
Temperature:________________°F______ Barometric Pressure:________________mmBar

PRIMARY FLOW STANDARD:
Make & Model:__________________ Property No:_____________Serial No:____
_______ Date Certified:________________________ Cert. Expires:_____________
____
0-30 sccm MFC: Airflow = ______________ X Display ± _____________sccm
0-100 sccm MFC: Airflow = _____________ X Display ± _____________sccm
0-10 slpm MFC: Airflow = ______________ X Display ± _____________slpm

ZERO AIR:
Source:______________________________ Property No:____________________
______
Outlet Pressure:________________psig

SET POINT NO.	SET POINT (slpm or sccm)	MFC FLOW VALUE (slpm or sccm)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

Calibrated by:_________________________ Checked by:_________________________

Figure K-6.Mass Flow Controllers Characterization Datasheet.

L APPENDIX L: AETHALOMETER OPERATING PROCEDURE

STATE OF IDAHO

DEPARTMENT OF ENVIRONMENTAL QUALITY

AIR MONITORING QUALITY ASSURANCE

STANDARD OPERATING PROCEDURES

FOR

AIR QUALITY MONITORING

THERMO (RP) SERIES 8100 AETHALOMETER MODULE

MONITORING, MODELING, AND EMISSIONS INVENTORY

DECEMBER 2005

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THERMO (RP) SERIES 8100 AETHALOMETER MODULE

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THERMO (RP) Series 8100 Aethalometer

Acronyms, Units, and Chemical Nomenclature

BC	Black Carbon
CFR	Code of Federal Regulations
DEQ	Department of Environmental Quality
RP	Rupprecht and Patashnick
SES	Sample Equilibration System
SOP	Standard Operating Procedure
TEOM	Tapered Element Oscillating Microbalance

REFERENCES

THERMO (RP) SERIES 8100 AETHALOMETER MODULE

This standard operating procedure (SOP) references the February 2005 manufacturer’s instruction manual for the Series 8100 Aethalometer Module as well as an SOP written for the Magee Scientific stand-alone aethalometer (Washington Department of Ecology). This document combines each of these instruction manuals into a general SOP in order to provide and accurate guidance and consistent format within the Quality Assurance Plan. Where differences exist between the two pieces of equipment, the Series 8100 manufacturer’s instruction manual will be referred to.

L.1 GENERAL INFORMATION

This document describes the procedures used to sample aerosol black carbon, hereafter referred to as BC, in ambient air using the THERMO (Rupprecht & Patashnick) Series 8100 Aethalometer Module (Figure L-1). The aethalometer module is a simple cost-effective means for users of TEOM monitors to measure the amount of BC contained in ambient particulate matter. The add-on module is a collaborative effort between THERMO and Magee Scientific. It is intended that this document be used together with the sampler-specific information and instructions provided by the manufacturer.

The aethalometer measures the mass of BC in a given volume of ambient air. The method by which this measurement is obtained is through a direct measurement of the absorption of light at various frequencies. Photons that strike particles in the air will be either absorbed or scattered. Scattered photons can be measured with a nephelometer. Absorbed particles are measured with an aethalometer. The amount of BC in the air is often a good indicator of the elemental carbon found in ambient particulate matter. Elemental carbon, often the result of combustion processes, can then be analyzed to gauge the effects of natural and man-made influences on the environment. The aethalometer measurement approach is the foremost method for real-time measurement of optically absorbing black carbon particles.

Figure L-1. Series 8100 Aethalometer Module (at right, connected to TEOM)

L.1.1 THEORY OF OPERATION

The aethalometer uses a method of optical attenuation to develop its value of BC in a given sample of air. A known quantity of air is passed through a fibrous filter. A specific frequency of light is applied to one side of the exposed filter and detected on the opposite side by a photodiode. The instrument calculates the quantity of BC in the sampled air using the value of light attenuation and the sample flow rate over a known period of time.

A reference photodiode is located below the filter media in an area where no aerosol is being collected. The signal from the main photodiode and the reference photodiode are mathematically combined in order to maintain a high degree of accuracy. This method of measurement eliminates any errors that may be introduced due to fluctuating light intensity.

The TEOM Series 1400a control unit allows the BC concentration data to be stored and displayed. The aethalometer module requires no programming, connects easily to the TEOM Series 1400a unit (in the bypass flow line), and uses the quartz fiber filter tape as its only consumable material.

L.2 EQUIPMENT AND SUPPLIES

- THERMO (RP) Series 8100 Aethalometer Module
- Power Cable
- Analog Connector Cable
- Hand tools
- 2 3/8-inch steel threaded quick connector
- 2 3/8-inch threaded swivel elbow quick connector
- 3/8-inch steel union fitting (for leak checks)
- 3/8-inch plastic plug (for leak checks)
- PC Software CD-ROM (for troubleshooting)
- RS-232 cable (for troubleshooting)
- Operating Guide
- Station Logbook

L.3 SITING REQUIREMENTS AND INSTALLATION

The Series 8100 aethalometer module is installed in the bypass flow stream of the TEOM Series 1400a unit or Series 8500 FDMS unit. It should be installed in the bypass flow line after the flow splitter, before the flow reaches the standard 1400a control unit or the Sample Equilibration System (SES), depending on the 1400 system setup. If the aethalometer module is to be placed inside an air conditioned enclosure in a location where the outside ambient air is sometimes humid, steps must be taken to minimize humid air from condensing in the line (as water can damage the sensor). The unit should be placed in the enclosure as near to the air inlet as possible and incoming line should be well insulated. An air heater may be required in severe conditions. Detailed installation instructions are provided in the THERMO (RP) Series 8100 Operating Manual (February 2005, Section 2).

Aethalometers can be used for a variety of monitoring applications. Because of this, specific siting criteria can not be detailed in this text. Comprehensive siting requirements can be found in Title 40 CFR 58, Appendix E. http://www.access.gpo.gov/nara/cfr/cfrhtml_00/Title_40/40cfr58_00.html

Aethalometers are commonly used in conjunction with nephelometers for measuring the quality of air with respect to visibility. If this is the case, the same siting criteria required for the nephelometer is to be adhered to.

L.3.1 BASIC SITING REQUIREMENTS

It is important to site the instrument far enough away from roadways to minimize any effects of re-entrained dust. Table L-1 a list of distances based on vehicles traveling the roadway:

Table L-1. Distance from Roadway

Less than 3000 cars per day	sampler should be $\geq$ 25 meters from road
3000 to 10,000 cars per day	sampler should be > 25 meters from road
10,000 to 20,000 cars per day	sampler should be > 50 meters from road
20,000 to 40,000 cars per day	sampler should be > 75 meters from road
40,000+ cars per day	sampler should be > 100 meters from road

- To keep impacts from wind blown dust to a minimum, stations should not be located on barren ground and should be located at least one quarter mile from potential sources of dust.
- Avoid areas with excessive smoke from local combustion sources.
- There must be no obstructions that would limit the module’s ability to collect aerosols representing the regional area.
- An open horizontal arc of at least 270^{O} or greater must surround the module inlet with prevailing winds entering the arc. Any obstructions within this arc must be twice the distance from the module inlet as they are tall.
- The probe inlet must be located between 2 and 15 meters above ground level.

Other factors must be remembered when considering a location for installation. The operator’s personal safety is an important consideration. It must be remembered that during times of inclement weather the site may still need to be accessed. Power & telephone line availability is a concern. Security of both the operator and the equipment can be an issue. Access to the site must be such that the operator has the ability to bring tools and supplies in and out. All sensitive electronic equipment must be kept in a temperature-controlled environment that isolates it from moisture and rapid temperature changes.

L.3.2 INSTALLATION OF THE AETHALOMETER

Upon receipt of the aethalometer, visually inspect it to ensure that all components are accounted for. Notify the Program Office immediately if any equipment is missing or damaged. Carefully transport the aethalometer module to the field site.

Proper installation of the module is very important. Care must be exercised to eliminate the possibility of drawing in water with the air sample.

Determine where to locate the aethalometer module and ensure it will be placed in the upright position on a flat, stable surface. Within a shelter, the location should not be directly impacted by the flow of air from a heater or an air conditioner. Follow the along with the THERMO (RP) Series 8100 Aethalometer Module Operating Guide, Section 2.2 (February 2005) for the step-by-step installation and setup directions.

L.3.3 SYSTEM OPERATION AND SETUP

Program the aethalometer according to specific data collecting requirements. The module transmits its data readings to the 1400a control unit through the ANALOG I/O connector in the back of the control unit. Set the analog jumper settings in the 1400a (Operating Guide Section 2.3.1 - February 2005) and the Analog Input Channel to 0 on the 1400a control unit to receive data from the aethalometer module (Operating Guide Section 2.3.2 - February 2005). If it becomes necessary to change the programming of the aethalometer, always follow the specific instructions located in the manufacturer’s Operating Guide.

L.4 FIELD OPERATIONS

The day to day operation of the aethalometer is relatively simple. Care must be taken to set the flow rate (specific to elevation), conduct leak checks, select the proper Sample Scale Range, and setup of the data storage parameters on the TEOM 1400a. All of these tasks should be completed by following the manufacturer's Operating Guide and the instructions in this SOP. When the aethalometer module is connected to a TEOM Series 1400a, there are no required gases, comparison standards, or data storage disks to be concerned with. Calibrations are done automatically within the aethalometer when necessary and data is logged on the 1400a's control unit. The operator must be aware of the remaining quantity of filter tape. Filter tape usage is based on parameters that were set during programming.

L.5 QUALITY CONTROL AND MAINTENANCE

L.5.1 BI-MONTHLY SITE VISIT

Do not exceed two weeks between site visits. Check the filter tape supply and replace if necessary. Tape replacement will not be necessary every visit, but take time to look over the module and ensure it and the TEOM are operating properly. If anything looks out of the ordinary, follow the monthly procedures below.

L.5.2 MONTHLY QC CHECK PROCEDURE

Because of the filter tape used in an aethalometer module, normal leak check procedures for the 1400/FDMS systems cannot be used with an aethalometer unit installed in the system. In a typical installation, with up to 3 meters of tubing between the aethalometer module and flow splitter, the vacuum inlet is well below one inch of mercury (34hPa). Typically, leak checks are performed at much higher vacuums which would create excessive leaks around the filter tape. Therefore, a union fitting is provided to splice together the lines that enter and exit the aethalometer module, allowing the balance of the system to be checked for leaks. This bypass of the aethalometer, with procedures explained in the Series 8100 Aethalometer Operating Guide, is needed to leak check the 1400/FDMS. For more information on leak check procedures for the TEOM Series 1400 and FDMS Series 8500 systems, refer to their respective operating manuals. A leak check of the parent sampler, with aethalometer module bypassed, should be conducted each month.

It may be desirable to leak check the aethalometer module itself, but it is not a required maintenance procedure. This may be completed by following the instructions in the Series 8100 Aethalometer Operating Guide (February 2005 - Section 4.3).

The aethalometer module requires virtually no operator intervention. Its routine maintenance activities consist of exchanging the spool of filter tape, generally on a 6- to 18-month interval, and cleaning selected internal components during the tape exchange process. A spool of filter tape has a capacity of approximately 1500 sample spots. Tape consumption ranges from several spots a day in locations of high BC concentration, to one spot per several days for background sites.

Follow the aethalometer operation manual for service and maintenance procedures.

L.6 DATA MANAGEMENT

Check the data logger via remote connection each day to ensure data is being collected.

L.7 DATA DOCUMENTATION AND VALIDATION

All data will be reviewed at the Regional Office level and must then be certified prior to being reported to the EPA, as well as prior to use in decisions concerning air quality management.

L.8 DATA QUALITY ASSESSMENT

For each calendar quarter and year, Regional Office staff will prepare data precision, accuracy, and completeness reports.

L.8.1 ACCURACY

Data accuracy will be evaluated and reported using results from the performance audits.

L.8.2 DATA COMPLETENESS

Data completeness will be determined for each module and expressed as a percentage. Percent valid data will be a gauge of the amount of valid data obtained compared to the amount expected under ideal conditions (24 hours per day, 365 days per year). Exceptions will be made for modules operating on a seasonal basis.

L.9 FORMS

Monthly Aethalometer QC Check Form

Aethalometer Maintenance Schedule

Monthly Aethalometer QC Check Form

Station Name ________________________

Station Number_________________________

Date________________________________

Operator______________________________

Temperature_______________________^{O}C

Barometric Pressure______________mm Hg

State ID or ID Number _________________

Flow at Ambient____________________lpm

DCN offline at ____________________PST

Flow at STP________________________lpm

DCN online at ____________________PST

Sampler Calibration Flow Rate Difference__________________________

Sampler Design Flow Rate Difference_____________________________

Flow at STP = Measured Flow $\times \left[\frac{298}{{}^{o}C + 273}\right] \times \left[\frac{BP}{760}\right]$

Sampler Calibration Flow Rate Difference $= \left[\frac{I - A}{A}\right] \times 100$

Sampler Design Flow Rate Difference $= \left[\frac{A - D}{D}\right] \times 100$

Aethalometer Maintenance Schedule

Site Name______________________________ **Site Number**_____________________

	Bimonthly			Monthly	Biannually	Annually	Operator
Date	Time Check	Display Flow	Tape & Disk	Actual Flow	Optical Strip Value	Probe Cleaned or Replaced	

Note: Initial each task as completed